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Final review of the GLORIA 2022-25 project

Summary report of the review performed by four external experts

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Abstract

The EU policy agenda highlights industrial innovation as key for competitive sustainability, together with the importance of monitoring and analysing innovation activity in Europe as a basis for research, innovation and industrial policymaking. Since 2004, the Directorate-General Research and Innovation (DG-R&I) and the Joint Research Centre (JRC) jointly produce the EU Industrial R&D Investment Scoreboards as main deliverables of the GLORIA (GLObal Industrial Research & Innovation Analyses) project. This report summarises key results from a peer review exercise by a group of four external experts to the GLORIA project - Jürgen Janger (Senior Economist at WIFO, Austria, coordinator as primus inter pares), Raquel Ortega Argilés (Professor of Regional Development, Manchester University, United Kingdom), Maria Luisa Mancusi (Professor of Economic Policy, Università Cattolica Milan, Italy and Daniel Gros (Director of the Institute for European Policymaking, Bocconi University, Italy). The findings of the review exercise were discussed and validated at an online workshop with the European Commission on 31 July 2025. The consolidated results of these activities are highlighted in this document.

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During 2025, the GLORIA project has been coordinated by from June onwards by Diana Ognyanova and until June by Evgeni Evgeniev (both Policy Officers, DG RTD.E1 'Industrial Research, Innovation and Investment Agendas') and Alexander Tübke (Team leader, JRC.B6 'Industrial Strategy, Skills & Technology Transfer') under the leadership of Doris Schröcker and Dominik Sobczak (respectively, Head and Deputy Head of Unit E1 'Industrial Research, Innovation & Investment Agendas', Directorate E, DG RTD) and Asunción Fernández-Carretero and Fernando Hervás (respectively, Head and Deputy Head of Unit B6 'Industrial Strategy, Skills & Technology Transfer').

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The main authors of this report are Jürgen Janger (Senior Economist at WIFO, Austria), Daniel Gros (Director of the Institute for European Policymaking, Bocconi University, Italy), Raquel Ortega Argilés (Professor of Regional Economic Development, The University of Manchester, United Kingdom), and Maria Luisa Mancusi (Professor of Economic Policy, Università Cattolica Milan, Italy). The document has been edited by Alexander Tübke (Team Leader Industrial Innovation & Competitiveness, European Commission, Joint Research Centre, Seville, Spain).

Executive Summary

- ⇨ The GLORIA (GLObal Industrial Research and Innovation Analyses) project´s main task is to monitor the R&D investment of global firms, producing the EU Industrial R&D Investment Scoreboard and related outputs. It was launched in 2003 due to the perceived R&D underinvestment by EU firms compared to their US competitors.
- ⇨ This report provides the summary of a review exercise conducted by four external experts for the project period 2022-25. The reviewers found that GLORIA is of very high quality, relevance and broad geographical scope, covering 90% of global business R&D. A key improvement was the establishment of a panel dataset.
- ⇨ Its relevance has increased even further since 2003: On top of a disappointing productivity performance, the EU now faces global competition between firms for dominance in key strategic technologies that could be exploited for political purposes.
- ⇨ The central EU policy challenge identified by GLORIA is the failure to scale up young firms in emerging or strategic technologies, or the insufficient structural change towards „high-tech" activities. Established firms don't spend less on R&D than their competitors; it is the lack of new firms in new sectors that drives the „innovation gap".
- ⇨ The review suggests building on the current framework to shed more light on this key issue. This could involve placing greater emphasis in the analysis on existing data such as market capitalisation or collecting additional data. GLORIA should monitor relevant scale-ups, unicorns and new emerging technologies such as artificial intelligence and the main players therein, even if they are not large enough to make it onto the Scoreboard list. This would involve using methodologies that complement the current main one.
- ⇨ While many EU-level policies are relevant for fostering new firms and technologies, such as further capital market integration or EIC funding, analysis of national-level drivers is limited by a lack of spatial information. Adding data on subsidiaries to complement headquarter-level data would strengthen GLORIA's evidence base.
- ⇨ GLORIA could also envisage to become a more general firm-level innovation competitiveness scoreboard by collecting additional data on the input and output of innovation processes, including intangibles, patent quality indicators, trademarks and designs, real product performance characteristics and better productivity measures.
- ⇨ The experts suggest a range of future research options, including research on the causal links be-tween R&D and outcomes, such as productivity or structural change; spillovers, the role of top R&D funders in technological developments, using network or supply chain analysis; on CVC and M&A activities; and on extending the data for EU firms back to 1995.
- ⇨ To foster external data use, the review suggests a modernised visualisation tool and more infographics. Research could be facilitated by enabling matching with other datasets.
- ⇨ So that policy messages can better take into account the full set of competitiveness drivers, the project needs additional expertise and data on regulation, university investment, wages, tax systems, education or infrastructure. This should be acknowledged, so that users of the data do not get a too narrow picture of the challenges of „closing the innovation gap".
- ⇨ All in all, the review suggests to supplement, not replace, GLORIA's excellent work, also regarding the green transformation.

1. Introduction

The GLORIA project (GLObal Industrial Research and Innovation Analyses) dates back to 2003. At this time, the European Commission published an action plan[1] to invest in research to reach the objective of R&D expenditures equivalent to 3% of GDP, set by the 2002 Barcelona European Council. The objective followed up on the Lisbon's Agenda ambition to make the EU the most competitive and dynamic knowledge-based economy in the world by 2010 and was confirmed in the EU´s long-term competitiveness strategy[2] and the Draghi report[3]. One of the proposed actions was the establishment of an industrial research monitoring activity including a Scoreboard against the background of a perceived underinvestment of EU firms in R&D.

Nowadays, the main objective of the project is still to monitor the global top R&D investing firms. It consists of four main tasks:

- Task 1: Producing the annual EU Industrial R&D Investment Scoreboard
- Task 2: Additional policy-relevant analysis around three main topics: directionality, industrial dynamics and the role of top R&D spenders in key networks and ecosystems.
- Task 3: Dissemination, discussion and validation of results through stakeholder involvement and communication, including the GLORIA workshops.
- Task 4: Within management & coordination, setting the GLORIA research agenda (task 2)

On top of the reports, working papers and other outputs, there is also an online visualisation tool. The Scoreboard data cover up to 90% of global R&D funded by the business sector, due to the concentration of business R&D in large firms. A key recent innovation was the establishment of a consolidated panel dataset covering more than 6.000 firms over the period 2003-2022 (700 firms are present over the whole period).

The evidence produced does not just include R&D funding, but also output indicators, such as paten-ts (the Scoreboard data are matched with Patstat) and several firm key performance indica-tors, including profitability, capital expenditures (Capex) and net sales. Furthermore, for the analysis of specific issues, further data are collected, e.g. for Merger&Acquisition (M&A) or corporate venture capital activities (CVCs). The main data source are audited company reports (usually public domain).

The evidence is used not only for the analysis of the competitive position of the EU in terms of R&D, but also for the analysis of policy priorities such as the green and digital (and twin) transition and more generally strategic technologies in the context of the EU's open strategic autonomy policy agenda which spans more than only the domains of defence and security. Ultimately, the Score-board is seen as a key evidence base for policies aimed to increase the EU's overall competitive-ness, with e.g. Commissioner Zaharieva pronouncing the Scoreboard in the 2024 report as a „…crucial tool to monitor industrial R&D investments in our pursuit of European competitiveness and prosperity". (Scoreboard 2024, p. 4). Or, in the words of the acknowledgements to the 2024 report, „the main expected impact of GLORIA is the better understanding of corporate Research & Development (R&D) efforts in relation to the EU's long-term 3% of GDP R&D investment policy target and the EU policy objectives regarding competitiveness, the green deal and sustainability". (Scoreboard 2024, p. 5).

[1] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2003:0226:FIN:EN:PDF

[2] COM(2023) 168 final

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

The project is regularly – every 2-3 years - reviewed by external independent experts. For the present 2025 review, the following four experts were asked to review the outputs of the GLORIA project:

Jürgen Janger (reviewer and team coordinator) is a senior economist in the Innovation, Industrial and International Economics research group at WIFO (the Austrian Institute of Economic Research). His main research interests are the economics of science and innovation, in particular, the measurement of innovation as well as science and innovation policies that can improve innovation performance. He has been engaged in a variety of innovation and science research and evaluation studies both at the European and national levels. In Austria, he is the lead contributor to an online monitor of research, technology and innovation performance which has been monitoring R&D and innovation for over 10 years. He was a member of the Steering Committee of the large-scale FP7 project 'WWWforEurope' that investigated the competitiveness of Europe, focusing on innovation and science. His work has been published in journals such as Research Policy, Higher Education, and Technological Forecasting and Social Change.

Professor **Raquel Ortega-Argilés** (reviewer) is the Chair of Regional Economic Development at Alliance Manchester Business School, The University of Manchester, where she leads the TPI Productivity Lab and the Knowledge Diffusion research programme at The Productivity Institute. Raquel is also a co-investigator in the Innovation Research Caucus and the Manchester Institute of Innovation Research. She is an expert in regional economic development, productivity, innovation and the economic impacts of shocks such as Brexit, Covid and digitalisation. Her scientific work has been published in various international academic journals and research books, employing approaches that range from advanced econometric and statistical modelling to case study techniques. Raquel serves as an associate editor for *Regional Studies, Global Challenges and Regional Science,* and *the Journal of Regional Science and sits in the editorial board of various other journals*.

Maria Luisa Mancusi (reviewer) is Professor of Economic Policy in the Department of Economics and Finance at the Catholic University of Milan (Italy). She is also a senior researcher and steering committee member of the Complexity Lab in Economics (CLE). Her research lies at the intersection of innovation economics and policy with international economics, industrial organization, and environmental economics. She has extensive experience in studying the determinants of firm-level innovation performance, as well as the effects of innovation and science policy instruments on industry dynamics and technological change. Her work has been published in leading international journals and covers a wide range of topics, including knowledge spillovers and absorptive capacity, path dependence in innovation, trade and technological specialisation, the relationship between outsourcing and innovation, R&D investment under financial constraints, the performance of new high-tech firms, and environmental innovation.

Daniel Gros (reviewer) is Director of the Institute for European Policymaking @ Bocconi University. Between 2020 and 2022 he was Distinguished Fellow and Member of the Board of the Centre for European Policy Studies (CEPS). Before that, he was the director of CEPS from 2000. In 2020, he held a Fulbright fellowship and was a visiting professor at the University of California, Berkeley. In March–June, 2022 he was visiting Research Fellow at the Robert Schuman Centre of the European University Institute, Florence. Previously he worked at the International Monetary Fund and collaborated with the European Commission as economic adviser to the Delors Committee, which developed plans for the euro. He is the author of several books (most recently 'Money in Crisis') and many scientific publications.

A kick-off meeting was held on June 20, 2025, after which the experts reviewed the following key outputs of the GLORIA project 2022-2025:

- 2022, 2023 and 2024 EU Industrial R&D Investment Scoreboard reports
- The working papers:
    - Long-term analysis of the impact of the EU Industrial R&D Investment Scoreboards in scientific publications and policy documents.
    - Long-term productivity policy brief.
- Seventh and eighth Gloria workshop reports

Each member of the group prepared an individual report that were summarised in a draft review report. The review team held two online meetings to gain a shared understanding of the GLORIA project, discuss the division of labour and discuss the structure and the focus of the reviews. The individual reports and the draft review report have been discussed in an online workshop on July 31, 2025. The report is structured as follows: first, we outline the main strengths of the project, before we suggest improvements to the analysis and communication of the results.

2. Summary of the review findings

2.1. Strengths of the project

The review team finds several strengths of the project, beginning with the observation that a **continuous monitoring of R&D and other firm-level variables contributes to an important evidence base for innovation, industrial and competitiveness policies**. The project provides useful quantitative, qualitative, and longitudinal empirical evidence to globally benchmark the EU's R&D investment capacity and a series of innovation outcomes. The Industrial R&D Scoreboard, in particular, has good visibility and is based on a reliable and well-established methodology of data collection and analysis.

Against this background, the project's **continuity since 2003 is a key strength**, in contrast to many other research or data collection efforts that have ceased after a few years. This provides for a long time series, that allows for detailed insights over time as regards R&D funding, firm performance and competitiveness. Recently, the project's data have been buttressed to establish a panel data set for the period 2003-2022. This is a major improvement, as it allows for the application of a variety of statistical methodologies that take advantage of panel data by comparison with cross-sectional data only.

In terms of the relevance of its data collection efforts and findings, the project has shown clearly that the EU's R&D gap to the US (and increasingly China) is not the result of neck-and-neck competitors in the EU doing less R&D than their global rivals (as a % of their sales), but of a failure to enter specific sectors, such as ICT hardware (semiconductors) and particularly ICT software and services. **It's often not the existing established EU firms that spend less (relative to their size), but the lack of companies in the high-tech sectors, especially young innovative firms that quickly scale up in new technology areas.**

This central finding has lost nothing of its relevance to current policy development. If anything, we face a similar if not worse situation than in 2003 regarding competitiveness in innovation-intensive industries and technologies: At that time, the challenge was mainly economic, to achieve the innovation performance necessary to boost productivity and thereby sustain its economic and social model. Today, the EU faces in addition the challenge of keeping up in strategic technologies to safeguard strategic autonomy or to avoid one-sided dependencies in critical technologies or materials that other countries could use as a political lever.

A recent report by Fuest and Gros[4] shows that the 'middle tech' specialisation of EU industry has increased over the last decades. Notably, the five largest companies in terms of R&D spending in the EU are all in the automotive industry (and in high tech in the US). Over the past two decades, the share of EU firms in the R&D in high-tech sectors has dropped by half—from 22% to just 11%. But one should not forget that R&D spending is not an end in itself. Investment in R&D should be a source of productivity and growth. **The work undertaken in the GLORIA project on the productivity of R&D investment thus represents an essential element.**

In summary, we find that the project is of very high relevance and quality, with global (geographic) scope.

[4] https://iep.unibocconi.eu/publications/reports/funding-ideas-not-companies-rethinking-eu-innovation-bottom

2.2. Main suggestions for improvement

While the GLORIA project is already very useful and relevant, the review team also identified a number of suggestions for improvement. Some of the issues could be addressed easily using existing data. However, some of the suggestions clearly require additional resources, as we do not suggest reducing some of the existing work done – we suggest keeping the current main pillars of the project and expanding it.

2.2.1. Additional data relevant for research and policy

The first batch of suggestions addresses broadly speaking collecting additional data that could increase the evidence base both for policies and for research. GLORIA is collecting a substantial amount of data in terms of firm performance that are relevant to assess R&D activities and (innovation) competitiveness, but in the following areas important complementary data could be collected:

- R&D data of subsidiaries on top of headquarters to assess R&D performance at country-level
- Monitoring of R&D activity and performance in key strategic technologies
- Include potential future in addition to current top R&D performers
- Future topics: artificial intelligence, dual use and defence, twin transition/green transformation
- Complement R&D and patent data with additional data to assess innovation processes
- Include all relevant players in the data set

We discuss these in turn. Some of the additional data do require considerable extra effort. We realise that, if substantial additional effort is required, our recommendations can only be implemented if resources for the project are increased, as we suggest keeping the current main pillars of the project.

2.2.1.1. R&D data of subsidiaries on top of headquarters to assess R&D performance at country-level

Currently, GLORIA collects R&D data (and other firm-level data) on the basis of audited company reports which are produced at the level of the headquarters. While the top R&D funders at the level of the EU are hence identified, and the comparison of the EU with the US and other regions or countries works well, the information at Member State level can be heavily distorted by the absence of data on subsidiary R&D activity. E.g., the Italian firm FIAT merged into Stellantis, which is now headquartered in the Netherlands. AIRBUS is also headquartered in the Netherlands, even though its main operational locations are in Germany and in France. The EU R&D Scoreboard can consequently not be used to monitor R&D and more generally competitiveness at the Member State level, even though many relevant policies are situated at this level. Analysing the role of **public funding for industrial R&D** would require (at least) the national level, as EU-level R&D funding is generally a small share of national budgets for R&D.

As a further result, determinants of **intra-EU R&D location choice** cannot be investigated, which would be both an important research avenue and evidence base for policy makers. Spatial mapping is moreover highly relevant to the project's stated aim of analysing how top R&D investors harness **globalisation** in their innovation strategies. Existing research has shown that knowledge creation increasingly occurs within international teams of inventors collaborating across borders within the same MNE (Belderbos et al., 2017; Castellani et al., 2017; Bircan et al., 2024). Furthermore, recent empirical work confirms that R&D activities conducted by foreign multinationals generate positive and significant spillover effects on local innovation systems (Crescenzi et al., 2022). These findings underscore the policy importance of understanding not just how much firms invest in R&D, but where they invest, and the broader implications for national as well as regional innovation ecosystems in the EU and beyond.

The observation of missing subsidiary data is not new – previous review reports and the GLORIA outputs raise this issue and are very transparent about it. Because of its research and policy relevance, we want to encourage the GLORIA team **to continue efforts to remedy this situation**, which would clearly ask for significantly more resources for the GLORIA project than allocated now. There has been a report in the past that suggests using patent data as a proxy for R&D activity. Patent data can be analysed using the location of the inventors, so that a company's patent portfolio – and hence R&D activity - could be geographically ascertained. This will not work perfectly, as a large firm has many subsidiaries and some of the subsidiaries will not have clear own identifiers that enable matching of data to the headquarter firm. But in our view, efforts should be undertaken to gain at least a rough picture of member-state-level R&D activity. Other methodological approaches can be tried, such as web scraping or big-data related approaches: using non-administrative or non-structured datasets, such as data from tagged data systems—websites or job advertisements—could provide the GLORIA project with greater detail. We have been told that a research contract investigating subsidiary data will soon be launched.

An important guideline for such efforts would be to develop an understanding of **how much „imprecision“ is acceptable**, weighing the benefits and disadvantages of having some, but not perfect information on country-level subsidiary data rather than none. Related to this is the question of how much the methodology for obtaining subsidiary data can be different to the one for obtaining headquarter-level data, or if lower-level data will be consistent with higher level-data. A first low-cost step could be to make the extent of the distortion explicit by **comparing R&D business funding data** by the statistical offices to the Scoreboard data for each country. The larger the deviation, the less useful the Scoreboard is for monitoring the country-level situation. Another potential data source for such "benchmark exercises" could be the EU KLEMS data or national surveys.[5]

2.2.1.2. Additional proxies for the competitive environment of relevant firms: monitoring of R&D activity and performance in key strategic technologies

To situate firms in their competitive environment, or to show them next to firms that operate in similar markets, GLORIA classifies firms by using broad economic sectors such as automotive, ICT software or aerospace & defence. It is not easy to group large conglomerate firms by sector or technology, as they often operate many business divisions that can be active in different, even broad economic sectors. However, in the past few years we have seen major issues with the EU's perceived competitive weaknesses in several key strategic technologies, such as artificial intelligence, high-performance semiconductors, batteries for EVs and several other areas.

The project is encouraged to use additional proxies to analyse the competitive environment of R&D funders that relate to the most pressing technological and policy priorities, as a standard feature of the Scoreboard, even if this implies using methodologies outside the current one to collect

[5] See papers by Claudio Cozza: https://ricerca.uniparthenope.it/handle/11367/73273 and https://core.ac.uk/download/pdf/38620818.pdf

headquarter-level data from company reports. There have already been selective efforts to do this, with e.g. special sections in Scoreboard reports such as the section on artificial intelligence in the 2023 report. This type of analysis is also relevant for the issue of directionality of R&D efforts, that is among the policy issues the GLORIA project addresses (see introduction).

Similarly to the point above, patent data can be used to show the activities of firms in specific technological classes that in turn can be grouped to build proxies for key enabling technologies. Other approaches involve again big data, such as text mining/web scraping of company documents, jobs or websites: Using website information allows analysis that goes beyond official, sector-specific classification schemes (such as SIC or NACE codes) and real-time data, which seems better suited to analysing fast-moving industrial trends, such as the adoption of artificial intelligence. An example of the use of website data to analyse digital, green or twin transition can be found in Cicerone et al. (2024). To keep the effort manageable, we suggest doing this only for a selected limited range of technologies. This could rely on existing classifications adopted at EU-level, e.g., the Advanced Technologies for Industry classification, or could mirror the EU strategic industrial policy agenda, with areas such as semi-conductors, artificial intelligence or quantum technologies, providing effective monitoring of relevant developments at the firm level.[6]

A further important improvement, relevant also for the following suggestion on future top R&D performers, would be not just to show the existing largest R&D funders by strategic technology, but to look at a strategic emerging technology and the R&D spent on this technology, or the patents filed, and then to show the largest firms within that technology. In new, emerging technologies, that could imply that firms that don't make it into the overall Scoreboard are listed. This would also allow for an interesting and relevant competitiveness picture in such technologies – who are the players, how do EU firms fare? This would provide crucial information for monitoring the activities of firms in key strategic technologies of high policy relevance, with significant benefits for EU-level policies such as the European industrial strategy, the Strategic Technologies for Europe Platform (STEP) or sectoral/technology-specific initiatives such as the CHIPS Act, the Quantum Europe Strategy, or the IPCEIs.

2.2.1.3. Include potential future top R&D performers in addition to the current ones

It has been suggested before to not just look at established large firms, but to also try and capture start-up activity to be able to show potential future top R&D performers. This is a crucially important policy area, as the EU's innovation gap in several technology-intensive sectors stems from a lack of young firms that have grown quickly: The key policy challenge that has been identified thanks to GLORIA is insufficient structural change towards „high-tech" sectors. Currently only the „receiving" end of this change is monitored, established large players, while disruptive start-ups on the „initiating" side are missing. To provide **earlier signals for structural change,** there are several proposals for enhancing the monitoring of prospective future high achievers, with varying resource requirements.

A first low-hanging fruit would be to always include in the analysis the **founding year** of the firms (albeit there will be difficulties due to firm dynamics, such as Google turning into Alphabet or Facebook becoming Meta), to be able to compare the average age of top R&D spenders in aggregate or sectoral terms.

[6] See e.g., https://strategic-technologies.europa.eu/index_en

Second, more emphasis could be placed on **market capitalisation** as an indicator of future growth opportunities. This indicator is already collected but will be limited to listed firms. Nevertheless, it provides important information on how markets see the future growth opportunities or competitiveness of firms. A notable example is the contrast between the EU and US automotive industries. While the EU is far ahead of the US in terms of R&D funding, the US is far ahead in terms of market capitalisation. This is mostly due to Tesla, but also to smaller upcoming firms such as Rivian, that achieves a market capitalisation close to the one of Volkswagen. In the Industrial R&D scoreboards, the automotive sector is called one of the EU strongholds. Examining market capitalisation might call this statement into question, particularly given the difficulties faced by European car manufacturers in producing competitive EVs. Market capitalisation does not just reflect the assessment of markets on the future competitiveness or growth opportunities of products. It is also linked to structural issues of capital markets and financing pensions, with EU capital markets being fragmented. But it is a signal that complements the input indicator R&D funding with a market-oriented outcome perspective. As a simple step, it could be included more often together with the analysis of R&D in the graphs and tables of the Scoreboards and other outputs.

A few attempts were made in the past to analyse the drivers of market capitalisation performance of EU firms in the context of the Scoreboard (see: Cincera et al., 2009). Aiming at comparing the market capitalisation evolution with their corresponding sectoral and stock market indexes and examining whether R&D intensity (measured as R&D investment relative to firm size) impacts stock market performance, the results indicated a positive correlation between R&D intensity and market capitalisation performance using both weighted (market cap-based) and unweighted (equal weight) measures. Other results from the panel data econometric analysis pointed out size effects as well as sectoral and geographical performance differences. These early findings already called for more granular data and extended analysis to generalise findings. With a longer time-series, analyses could be focused on how firms with consistent R&D investment show more stable market capitalisation growth than those with volatile investment.

Third, **top players by emerging/strategic technology** could be shown **independent of size** (see bullet point above on strategic technologies) – our suggestion on potential future top performers is closely related to the monitoring of strategic technologies, as it is in particular young firms in these technologies or sectors that drive relevant structural change that can bear upon strategic autonomy or economy-wide growth and productivity opportunities.

Fourth, the GLORIA project already uses start-up and venture funding databases such as Dealroom. While many start-ups come and go, the largest ones, or the most successful ones with respect to funding, **unicorns**, could become part of a yearly monitoring to be included as a separate section in the Scoreboard, as an example, that may not have R&D as a main variable but rather available data such as the amount of venture funding the unicorns receive. Their number and size could be compared between regions on aggregate, pinpointing general firm dynamics. But they could also be classified by sectors and strategic technologies, potentially allowing for an analysis of the directionality of start-up activity in the various regions: are unicorns in the EU strengthening established EU sectors, or are they venturing into new areas where the EU is currently weak? Such an analysis would be very important to inform competitiveness policies, as it would be forward looking and picking up early „success“ or „failure“ signals of EU policies in strategic technologies. Specific relevant EU policies are, e.g., the EU Startup and Scaleup Strategy, the New European Innovation Agenda and the European Innovation Council.

Moreover, comparing the innovation patterns of top R&D funders with those of younger, emerging firms could yield valuable insights, particularly in sectors undergoing rapid technological transformation. Younger (and more agile) firms are often at the forefront of cutting-edge or disruptive innovation and may serve as leading indicators of future technology trends. Such a comparison could help policymakers understand whether incumbent corporate investors are driving, adapting to, or lagging behind emerging innovation trajectories, especially in pivotal domains like digital health, clean energy, or advanced manufacturing.

2.2.1.4. Future topics: artificial intelligence, dual use and defence, twin transition and green transformation

This suggestion partly overlaps with strategic technologies. The GLORIA team has already looked in the past at specific topics such as artificial intelligence which is a key EU policy area. In our view, **artificial intelligence** proceeds at such speed that the Scoreboards should look at firms in this area every year, e.g. from the aspect of using the technology – the intersection of AI with other sectors, for example in health - but also of producing it. But the analytical framework needs to be adapted, so that the “real” leading players in an emerging technology are captured. The 2023 analysis of artificial intelligence in the Scoreboard, while using a lot of different data, fails to capture the most important emerging players such as OpenAI or Anthropic, but also the main large firms active in AI (and present in the Scoreboard), such as Alphabet, Microsoft or Meta. If the standard methodology does not lead to the identification of the most important players, alternative approaches need to be tried. Moreover, as the ecosystem analysis has shown, AI has become an issue for a very broad field of organisations. The analysis would hence have to be carefully focused so as not to require too many resources.

Otherwise, a clear candidate for a future specialty section is **dual use and defence** where EU activities and analyses have been picking up steam, as well as the **twin transition** digital and sustainability. Topics linked to the **green transformation** have been addressed in the past, e.g. in the Scoreboard reports and in additional papers. They will continue to be very relevant and important, as climate change is here to stay unless properly addressed. Rising temperatures and extreme weather events will continue to impact firms’ activities and results and hence be a major factor for their R&D and innovation strategies, that will only grow as the effects of climate change will become even worse over time. EU-level policies such as the Clean Industrial Deal that aim at both competitiveness via affordable energy costs and at supporting the transition to a low carbon economy will hence continue to be very relevant, and the data collected by GLORIA that is relevant for these policies and efforts, such as the analysis of green patenting, will continue to be an important evidence base even though the data may not need to be collected or analysed every year.

2.2.1.5. Complement R&D and patent data with additional data to assess innovation processes

Currently, GLORIA collects R&D data, which can be seen as an input for new products, as well as patents, that are outputs of innovation processes but also inputs for new products. Firm-level outcome data such as profitability of market capitalisation do not necessarily relate to the success of R&D and patents alone, other factors such as macro-economic demand, wage costs, differences in regulatory environments and others also impact on firm-level key performance indicators. The same holds true for the measure of labour productivity e.g. adopted in the paper on R&D productivity. It only employs net sales per employee, a measure of value added would be much preferable, e.g. by introducing costs. On the input side, R&D is not the only relevant factor for innovation, many other factors such as the quality of skills or more general intangible investment shape innovation processes.

To more narrowly monitor the success of innovation processes, one option on the output side could be to collect **real product performance characteristics** that illustrate the quality or performance of key products. Examples would be, in the automotive sector, EV reach & charging time, or width of semiconductor production processes. This will be resource-intensive and would likely only be useful for limited, selected key strategic technologies (artificial intelligence, batteries, EVs, high-performance chips...); although doing this supported by AI may keep efforts manageable. It would provide a very clear picture on the outcome of R&D activities and the associated competitiveness of firms in the marketplace. A case in point could be the 2023 analysis of AI in the Scoreboard, that does neither identify the main big players in the Scoreboard in AI (Alphabet, Meta, Microsoft, …) nor the emerging smaller (but technologically leading) firms such as OpenAI or Anthropic. Finding a way to compare the performance of large language models could remedy the drawback of the existing methodologies.

Another important dimension of innovation processes is the balance between process and product innovation. Recent methodological advances allow for this distinction to be captured using patent text analysis. Notably, Banholzer et al. (2019) developed a method to estimate the process innovation share of patents filed at the EPO and USPTO by applying keyword searches to independent claims in patent documents. Similar techniques have been adopted by Branstetter et al. (2021), who investigate how offshoring influences not only the volume but also the nature of innovation. Their findings suggest that increased exposure to offshoring can reduce overall innovation levels and lead to a strategic shift away from product innovation towards process-oriented approaches. The observed decline in R&D productivity could also at least partially reflect firm-level maturity effects rather than an economy-wide innovation deficit. Indeed, the literature (e.g. Pellegrino and Piva, 2020) has shown that larger and older firms tend to shift from product innovation to process innovation, the latter being less frequently patented and therefore harder to measure through patent-based R&D productivity metrics. Therefore, it would be important to account for firm age, firm heterogeneity, and the role of smaller and emerging actors.

Given the known drawbacks of patent data, another option on the output side would be the incorporation of **trademarks or designs**, in particular to consider innovation results by sectors or smaller-sized firms (see Castaldi et al., 2021); or the introduction of patent quality indicators that go beyond patent counts (albeit usually at the cost of longer time lags).

And finally, on the input side, R&D is part of the broader category of **intangibles**, that include e.g., expenditures on software or marketing (potentially leading to trademarks and designs). The growing importance of intangible investments is an important phenomenon of modern knowledge-based economies (Haskel and Westlake, 2017) and merits more attention in the GLORIA project.

2.2.1.6. Include all relevant players in the data set

Because of issues with the classification of data in its company report, Amazon does currently not feature in the data set, although a separate box in the 2024 Scoreboard tries to identify a potential range of R&D funding. Similar to the issue with R&D activities by subsidiaries, we feel that a rough estimate – or a range – of the R&D funding of the potentially largest R&D funder in the world should be part of the dataset, appropriately and transparently flagged. Graphs and tables could show the situation with and without Amazon, to assess the importance of the firm and the impact on the gap of the EU with the US.

As a general point, we feel that it would be more important to include data – appropriately flagged – even if not perfect, rather than leaving it out.

2.2.2. Using and communicating the data

The second batch of suggestions concerns communicating, or showing the data, as well as using it for research or policy purposes. Here we suggest the following improvements as a pathway for higher impact of the GLORIA project:

- Facilitate research and matching data by including firm identifiers
- Take advantage of the new panel data set
- Increase use of infographics and linked tables in reports
- Modernise the online interactive visualisation tool
- Be more explicit about limitations of the data
- GLORIA workshops

We discuss these in turn.

2.2.2.1. Facilitate research and matching data by including firm identifiers

Currently, there are no statistical identifiers provided in the datasets that can be downloaded. E.g. BVDid would allow easily merging with Orbis and its IP and M&A modules, firm id in Patstat would help merge with patents. This severely limits working with the data for own research and analytical purposes, in particular if other data sources have to be matched to the Scoreboard dataset. Use by academic researchers is somewhat limited (JRC WP CoRDI 03/2024). Besides, patent data are available on a different website and are a little too fragmented.

2.2.2.2. Take advantage of the new panel data set

The GLORIA project should exploit longer series in data by revisiting previous analyses performed in the past on R&D and productivity or R&D intensity disparities between the EU and other counterparts to gain a significant understanding of how international shocks such as Brexit, Covid-19 or geopolitical situations may have affected investment and the positioning of industries in Europe and beyond.

2.2.2.3. Increase use of infographics and linked tables in report

The use of infographics or visualisations is growing, as well as the use of tables or graphs that are linked to the underlying data, accessible via hyperlink. The outputs of the GLORIA project show potential to increase the use of such tools. They would make it easier to understand the data provided, but also to make the data used even more transparent. Visualisations should incorporate a weblink to the dataset used to create the visualisation, similar to those contained in OECD publications.

It would be interesting to create a repository of visualisations or infographics that accompany each edition of the Scoreboard. These infographics are primarily visualisations included in the report, accompanied by a statement of support that can be easily incorporated into a presentation or other reports. Such a collection will increase the project's visibility while granting authorship to the creator of the visualisation. Examples of such a collection could be found here: Comparing productivity performance across the UK using scorecard maps

In addition, the website could create small data tools with the Scoreboard data that allow the users to create visualisations that are easily downloadable. This could improve the accessibility and increase the usage of the data. Examples of data tools can be found here: Tools

2.2.2.4. Modernise the online interactive visualisation tool

We suggest improving the current online visualisation tool both with regard to its technological implementation and with regard to its contents, that is the data it shows and what users can do with the data offered. Online interactive data tools have become much more widespread, and increasingly, users of the data don't read long reports, but rather inform themselves online using the interactive tools. First, the technological implementation is quite slow by comparison with other interactive tools, such as the one by the European Innovation Scoreboard, or other ones at national level, such as the Austrian Council's innovation monitoring performance tool.

Second, not all data that are collected are available online. As an example, only absolute numbers of the variables are present, but not percentage shares. This would be very relevant information, e.g., to compare R&D intensity or profitability, rather than total R&D or profit, across firms and regions. Also, country/region and industry averages would be very informative to situate the figures of individual companies; as well as country/region and industry totals, to show shares of individual firms, and hence their importance. Data are only available online from 2018 to 2023 rather than from 2004.

Third, the analytical capabilities are very limited, with the default graph type being a tree map. Future improvements to the tool should allow for, e.g.:

- tables where users can rank firms according to the indicator of their choice, e.g. within their sector, within a country or across countries.
- timeline graphs, allowing for e.g. visualising the top 10 firms in a sector since 2004, which would be very interesting in terms of competitiveness analysis or firm dynamics
- manually selecting individual firms to be compared with each other ("neck-and-neck competition")
- switching between the broad sector classification and more detailed technologies, if the suggestion in section 3.1 on technologies is implemented

Fourth, there could easily be links placed on the website, connecting to other scoreboards, in particular the European Innovation Scoreboard that monitors aggregate national or country-level performance, and the Regional Innovation Scoreboard that monitors regional innovation performance, with the EU Industrial R&D Scoreboard being the firm-level monitoring tool. This "hierarchy" could easily be shown in a clickable bullet point list (national – regional – firm-level).

Fifth, there is no explanation of the headquarter-based data. There should be a footnote for the country indicator, or any other way of signalling that the country selection needs to be regarded with great caution. Here, it would help to have a comparison between official country BERD statistics and the scoreboard, so that viewers can assess the extent of the differences (see point above on subsidiaries).

There is the potential for many more features, of course, but implementing a limited list of improvements could already greatly improve the usefulness of the online tool for policymakers, journalists, firms and researchers.

2.2.2.5. Be more explicit about limitations of the data

Finally, while the GLORIA outputs are generally transparent and provide methodological details, we encourage the team to provide more information about caveats. An example was mentioned just above, in that the headquarter-based concept is not flagged in the online visualisation tool; another example is e.g., the working paper on R&D and productivity, that does not discuss the potential implications of using sales per employee rather than value added per hour, or total factor productivity.

Moreover, the policy sections – such as section 4.5.2., bullet point 3 in the working paper on the impact of the Scoreboard should acknowledge further policy dimensions that are relevant for the success of young firms: Determinants of structural change towards knowledge-intensive activities (the key policy challenge that comes out of the Scoreboard) regard a wide range of factors on top of R&D and innovation, such as product, labour and capital market regulation, the strength of universities, wages & tax system, infrastructure etc. Sometimes, the project outputs don't reflect this in their policy messages – readers get a **too narrow glimpse of the policy challenges involved**. Next to industrial R&D investment, e.g., also investment in universities is very different across the Atlantic (and even within Europe, when comparing top UK or Swiss universities with top EU universities).

Short references to other relevant EU-level reports or academic literature would be enough to signal caution and the need to go beyond the Scoreboard when investigating policies to close the EU's deficits, such as the "innovation gap" described in the Draghi report. This is an important point for the communication and formulation of policy messages arising out of the GLORIA project – **heed the wide range of potential determinants of firm competitiveness**.

Sometimes, it is enough to simply heeding the full range of Scoreboard data or taking into account all the data that are collected. E.g., using market capitalisation in addition to R&D investment to characterise strengths and weaknesses would qualify the performance of the EU automotive sector that is currently called a "stronghold" in the Scoreboard.

2.2.3. GLORIA workshops

The specific objectives of the Workshops vary significantly. In the 7th Workshop Report, there is simply one keynote address on the Scoreboard in a wider workshop/conference setting. Here the objective seems to be getting the project known among people that work on similar topics. In the 8th Workshop Report, the project and the Scoreboard are centre stage, likely due to the 20-year-celebration since its existence. More clearly specifying what the **purpose of the workshops should be and adjusting its timing** could potentially help with this dissemination activity.

As an example, the workshop could take place after the work is finished, but before it is officially published, to an audience of policymakers and researchers. Key aspects could be presenting the results and then collecting feedback: what do the results mean for policy, e.g. for the various EU industrial strategies or policies (see links in the preceding sections)? Are the results on their own sufficient to motivate policies, or do we need further research? Where are caveats that need to be borne in mind when interpreting the results? Here, the work of the team would be centre stage, and both results would be disseminated as well as feedback collected on the results and methodologies of the report. Conversely, the workshops could take place at the beginning of the work, and after presenting last year's results, collect feedback from policymakers and researchers on their expectations from the Scoreboard, what they would need in terms of data to support their policies or which data need to be collected to enable specific research methodologies for more academic work.

3. Suggestions for the future research agenda

Task 2 of the project explicitly addresses policy analysis, but the data set could of course be exploited more with a view to research and policy analysis. However, the question is whether this should be done within the GLORIA team, or whether it should be external researchers that use the data collected by the project. A focus on the second requires additional information such as firm identifiers that can be used to match the data with other data sets. A focus on the first quickly runs into constrained resources for the GLORIA project. In the view of the review team, both directions should be followed - some in-house research and policy analysis capability is necessary as the insights will feed back into the data collection effort. But it is also important that external researchers that are independent of the European Commission can use the data and reach their own conclusions with regard to the Scoreboard data, potentially challenging in-house results. Such conflicting results can stimulate learning and be discussed, e.g., during the GLORIA workshops.

Some potential research avenues - on top of the ones mentioned in the preceding sections - are the following:

- There is still limited evidence in the pathways of impact between R&D investments and innovation and performance outcomes, such as limited exploration of causality – causal mechanisms or feedback loops between R&D data and policy shifts. A key question, e.g., is what drives the structural change towards knowledge-intensive activities (the key policy challenge that comes out of the Scoreboard) – what is the role of R&D and innovation relative to other factors (e.g., human capital, capital expenditures or physical capital, intangibles such as ICT)?
- Spillovers: While the concept of spillovers is mentioned, it doesn't fully unpack how Scoreboard data might explain cross-sectoral or regional spillover effects. Opportunities for collaboration with other groups within the JRC are clear, particularly with modelling groups such as the FIDELIO or RHOMOLO input-output models, which could allow experimenting with scenario analysis, forecasting techniques or multiplier analysis. Example of scenario analysis for R&D mission implementation: pure.manchester.ac.uk/ws/portalfiles/portal/297809545/mioir.wp.2024-03.pdf
- Incorporate firm-level dynamic panel regressions with special attention to the comparison of sectoral performance such as in Ortega-Argilés et al. (2011)
- Incorporate more geographically comparative analysis such as in Ortega-Argilés et al. (2014).
- Incorporate other output measures such as firm efficiency (Kumbhakar et al., 2012); labour productivity is currently calculated as net sales per employee, which could be, depending on the sector, quite different to value added per hour worked (which is also not a good outcome measure for R&D, preferable would be total factor productivity)
- Span data by incorporating information on workforce diversity or skill composition to explore how talent dynamics influence R&D productivity and innovation diffusion.
- Explore the use of input-output methodologies or network analyses to explore dependencies between R&D intensive firms and upstream/downstream sectors. This could be by collaborating with other JRC groups such as the teams of the FIDELIO or RHOMOLO models.
- CVC (Scoreboard 2022) and M&As (Scoreboard 2024) are very interesting exercises, that could be further deepened and systematically included in the Scoreboard analysis because

they represent complementary strategies to R&D investment for established players, particularly in view of the reduction in R&D productivity (Scoreboard 2024).

- Patent data availability may be further exploited. For example, it might be interesting to see if patents by top investors are more/less complex, valuable, radical… than patents from other firms. This can be easily done by using OECD patent quality indicators. It would also be interesting to see if top investors move more towards process rather than product innovation compared to other firms. This can be seen again using patents (Banholzer et al., 2019). The focus could be on the comparison with young firms, whose innovation might better represent current and future technology trends.
- It would be interesting to better assess the actual role of top R&D funders in technological developments and their impact on other firms, their innovation and growth. This can be done in different directions. Here are some:
  a) Using network analysis (with patent citations, co-patenting) to establish top funders' position and role in the network (e.g. with centrality measures), assess their role as gatekeepers and see how they relate to other relevant actors in the network.
  b) Reconstructing supply chain relationships to obtain the network of suppliers and customers and use it to assess the impact of top funders on their innovation.
- Entrepreneurship and firm growth are key sources of industry dynamics. As such, CVC investments are a channel through which top R&D funders exert an indirect effect on industry dynamics. An equally important one would be spin-offs, and some effort could be devoted to integrating information on this in the data (using existing databases, linked-in data, web scraping, etc.).
- Top innovators might breed spin-offs and entrepreneurs, but might also buy start-ups to preserve market power, block start-ups to enter, kill new innovators (buy to kill vs buy to grow). Some of this is in the 2024 Scoreboard but could be further expanded. Looking at patents financed by (CVC) and acquired companies before and after financing or acquisition to assess the impact and strategies of top investors across time and sectors.
- We would recommend a one-time effort to extend the data for the biggest 500 EU and non-EU firms backwards to about 1995 before the dot.com bubble or the "New Economy". This would provide a longer time horizon (e.g. did the mid-tech trap apply already then?).

4. Conclusions

GLORIA has always been an important and relevant monitoring project providing crucial data as an input into an evidence base for R&D, innovation, industrial and more generally competitiveness policies. Recent global events that challenge the international rules-based order and that have highlighted the vulnerability of the EU in key strategic technologies, as well as a disappointing economic performance of the EU have further added to the importance of the project. It is already a central monitoring tool for the progress and effect of EU and member-state innovation, industrial and competitiveness policies. By collecting a range of additional relevant data as outlined above, it could become even more central an information source.

Some additional data would be particularly relevant to shed more light on the central EU performance issue that GLORIA has identified over the years: a failure to scale up young innovative firms in key emerging or strategic technologies or insufficient structural change towards strategic knowledge-intensive activities. Currently only the „receiving“ end of this change is monitored, established large players in broad economic sectors, while disruptive start-ups in emerging technologies on the „initiating“ side are missing. Finding ways to collect data on both scaleups and strategic technologies would increase further the usefulness of GLORIA for research and policy.

This discussion touches also upon the role of R&D as a determinant of (innovation) competitiveness. While R&D is certainly very important, it is not the only decisive factor for closing the “innovation gap”. It is only part of the more general category of intangible assets that have been found to drive the success of large innovative firms. While keeping the R&D monitoring as an important backbone of the project, GLORIA could make more use of the many other data it already collects, but also widen the data it collects as suggested both on the input and output side of innovation processes, to become a more general firm-level innovation competitiveness scoreboard, complementary to the national-level European Innovation Scoreboard and the regional-level Regional Innovation Scoreboard. This however clearly asks for more resources to carry out the analytical tasks necessary, even if the availability of data and (AI-driven) methodologies for analysis have become better. In our view, given the importance of the Scoreboard in the current challenging times, and the importance of the competitiveness policies that it informs, these additional resources would be justified. In such a wider setting, the role of the 3% R&D goal for (innovation) competitiveness could also be analysed in more detail. **The fundamental rationale for the project should be contributing to relevant evidence for closing the innovation gap of EU industry, which goes beyond R&D.**

One must also bear in mind that even if more data are added, there would still be many other determinants of competitiveness that are beyond the scope of the Scoreboard, such as product, labour and capital market regulation, or the strength of the science base, relevant topics where the EU faces deficits and which are, inter alia, addressed by the Draghi report. Such missing pieces should be acknowledged more explicitly in the Scoreboards and other outputs, so as not to overly narrow the discussion on relevant policies to close the EU’s innovation gaps, as well as the limitations of the data. We also suggest improvements as a pathway for higher impact of the GLORIA project, such as an increased use of infographics, a modernised online visualisation tool and facilitating increased use of the dataset for external researchers.

To conclude, the GLORIA project produces relevant data and research of very high quality. Its geographic scope is global. We suggest several ways to add relevant data, which could further increase the “data” scope of the project, as well as ways to boost dissemination and communication of the results. **These suggestions should be implemented on top of the existing project pillars and not replace the important current backbone of the project.**

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List of abbreviations and definitions

Artificial intelligence (AI)

Capital expenditure (Capex)

Critical raw materials (CRM)

Corporate venture capital (CVC)

Digital Decade (DD)

European Industrial Research Management Association (EIRMA)

European Research Area (ERA)

EU Industrial R&D Investment Scoreboard (Scoreboard)

European Commission (EC)

European Commission, Directorate-General for Research and Innovation (DG RTD)

European Commission, Joint Research Centre (JRC)

European Investment Bank (EIB)

European Innovation Council (EIC)

European Innovation Scoreboard (EIS)

European Innovation Council and SMEs Executive Agency (EISMEA)

European Institute of Innovation & Technology (EIT)

European Union (EU)

Global Innovation Index (GII)

Horizon Europe (HE)

Information and communication technology (ICT)

Intellectual property (IP)

Mergers & acquisitions (M&A)

Questions & answers (Q&A)

Public-private partnership (PPP)

Research & development (R&D)

Research, development and innovation (R&D&I)

Research & innovation (R&I)

Small and medium-sized enterprises (SMEs)

Science, Research & Innovation Performance (SRIP)

Science, Technology, Engineering, Mathematics (STEM)

Strategic Technologies for Europe (STEP)

Technology readiness level (TRL)

Technology transfer organisation (TTO)

United Kingdom (UK)

United States of America (US)

Venture capital (VC)

World Intellectual Property Organisation (WIPO)

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