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Working Paper The impact of the EU Industrial R&D Investment Scoreboard in science and policy

JRC Working Papers on Corporate R&D and Innovation (CoRDI), No. 03/2024

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The impact of the EU Industrial R&D Investment Scoreboard in Science and Policy

JRC Working Papers on Corporate R&D and Innovation (CoRDI) No 03/2024

Confraria, H.; Grassano, N.; Moncada-Paternò-Castello, P.; Nindl, E.

2024



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Abstract

Understanding the flow of knowledge between scientific research and policymaking is increasingly important. This study examines the influence of the EU Industrial R&D Investment Scoreboard, a monitoring report produced for policy makers, researchers, and businesses since 2004. We analyse citation trends in scientific publications and policy documents to assess the Scoreboard's usage, reach and impact. Our findings indicate that the Scoreboard is cited more frequently in policy documents, though academic interest is growing. Policy documents cite the Scoreboard more quickly, reflecting its immediate relevance, while scientific publications take longer to cite it and utilise its data. Papers citing the Scoreboard tend to have a higher citation impact than average, and appear in a wide range of disciplines and journals. In our citation content analysis, we find that "insight" citations are more common than "data" citations. However, publications combining patent and Scoreboard data tend to receive more citations, highlighting the value of integrating R&D data with other relevant variables to better understand the innovation process. Finally, we show how the Scoreboard has influenced EU policy discourse to address the need for structural changes towards high R&D intensity sectors, and showing EU's leadership in green innovation.

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Executive summary

The EU Industrial R&D Investment Scoreboard, established in 2004 by the European Commission - Joint Research Centre (JRC) and Directorate-General of Research and Innovation, has become a key tool for monitoring corporate R&D investment and informing EU policy. This paper analyses the Scoreboard's impact over the past 20 years, focusing on how it has been used in both scientific publications and policy documents, revealing valuable insights about its influence on both academic research and policymaking.

Key Findings:

- 1. Policy impact:
 - The Scoreboard has been instrumental in shaping EU policy, particularly by highlighting the need for structural changes towards high R&D intensity sectors and showcasing the EU's leadership in green innovation.
 - Core users include the JRC, DG RTD, and DG GROW, with growing citations by think tanks, indicating the broadening policy impact of the Scoreboard.
 - The Scoreboard is cited more frequently and more quickly in policy documents compared to scientific publications, showing its immediate relevance for policy discussions.
- 2. Scientific Impact:
 - While policy citations dominate, there is a growing academic interest in the Scoreboard, with an increasing share of citations coming from scientific publications.
 - Citations in scientific research span from a diverse range of actors and topics, including innovation, health, governance, and artificial intelligence, demonstrating the Scoreboard's broad relevance.
 - Publications citing the Scoreboard tend to have relative high impact, particularly those combining Scoreboard data with patent data.
- 3. Citation Patterns:
 - Insight Citations: More frequent than data citations, focusing on practical findings of Scoreboard analysis, such as R&D trends, sector-specific insights, and global benchmarks.
 - Data Citations: Take longer to emerge and often involve integrating Scoreboard data with other datasets, particularly in studies looking at the effectiveness of R&D investments or R&D spillovers.

The Scoreboard has proven to be an essential resource for both researchers and policymakers involved in innovation policy, bridging the gap between scientific evidence and policy decisions. Its insights have shaped discussions on industrial R&D, innovation, and the EU's competitiveness, particularly in green technologies and structural transformation. As its relevance continues to grow, the Scoreboard remains a vital tool for ensuring that R&D data informs both science and policy in the EU.

1 Introduction

Understanding the flow of knowledge between scientific research and policymaking is increasingly crucial in addressing societal challenges such as climate change, public health crises, or the impact of technological advancements such as artificial intelligence. International organizations like the European Commission's Joint Research Centre (JRC) play a vital role in this science-policy interface, providing analyses, advice, and technical expertise to support European Union (EU) policies (Gluckman et al., 2021; Topp et al., 2018).

While there is growing research on how scientific findings are cited in policy documents (Pinheiro et al., 2021; Yin et al., 2022; Yu et al., 2023), less attention has been paid to the reciprocal relationship – how policy documents are used by policymakers or cited in scientific research. This paper aims to contribute to this gap by employing bibliometric and citation content analysis to investigate the influence of a policy document, the EU Industrial R&D Investment Scoreboard, on both, scientific research and other policy documents.

The EU Industrial R&D Investment Scoreboard ("the Scoreboard"), established in 2004 by the JRC, constitutes a significant resource widely utilised by researchers and policymakers.¹ It offers comprehensive monitoring and analysis of economic and financial data of the top corporate R&D investors worldwide and provides policy recommendations for the European Commission (EC) based on its empirical findings. Aligned with the EU's research and innovation policy agenda, the Scoreboard serves as a central tool for investigating private sector R&D investments over time, across sectors, and regions. Since its inception, the Scoreboard has also aimed to inform the public, to enable firms to benchmark their R&D efforts against their peers, and to allow researchers to conduct their own analyses.

Our search reveals that up to 2023, the Scoreboard has been cited in 347 scientific publications across 206 different journals indexed in the Web of Science Core Collection (WoS), and in 658 policy documents indexed in Overton. We use this data to examine citation trends in scientific publications and policy documents, identify the institutions that frequently reference the Scoreboard, assess its impact in different fields and topics, analyse dynamic changes in types of citations (e.g., data, insights), and understand the contributions of the Scoreboard to policy proposals.

Specifically, we address three main research questions quantitatively and qualitatively:

- 1. To what extent have Scoreboard insights and data been cited in scientific publications and policy documents?
- 2. Has the Scoreboard provided new insights about corporate R&D to science and EU policy?
- 3. Are scientific publications using the Scoreboard influential?

In the next section, we provide background on this study and its potential contributions to the discussion on how policy documents can facilitate the diffusion of knowledge between science and policy. Section 3 describes the methods employed, Section 4 presents and discusses the main results, and Section 5 concludes.

¹ Produced since then by the European Commission's Joint Research Centre in collaboration with the General-Directorate for Research and Development of the European Commission.

2 Background

2.1 The role of international organisations in the science-policy interface

While international organisations, such as the JRC of the European Commission², are increasingly acknowledged as important actors in both science and policymaking (Loevestam et al., 2024; Zapp, 2017), there is little work on these organisations' knowledge output.³

These boundary organisations operate at the intersection of different knowledge communities and policymakers, aiming to facilitate the flow of information and enhance evidence-based decision-making. Their roles are multifaceted and can include aspects related to policy advise and support, data collection and analysis, monitoring and evaluation, facilitating collaborations and networking, or knowledge dissemination (Gluckman et al., 2021; Pielke, 2007; Šucha and Sienkiewicz, 2020; Williams, 2002).

In the realms of data collection, monitoring, and evaluation, international organisations play a particularly crucial role in three main aspects:

a) Setting global targets and promoting data collection: International organisations formulate and disseminate new global targets related to socio-economic development, public health, environmental sustainability, and other evolving challenges. They define targets and performance indicators to facilitate policies and establish robust frameworks for data collection, monitoring, and analysis. These efforts catalyse global initiatives, mobilise resources, foster policy coherence, and drive evidence-based decision-making at various levels. By galvanising global efforts towards common objectives (such as the Sustainable Development Goals), these initiatives serve as catalysts for mobilising resources, fostering policy coherence, and driving evidence-based decision-making at local, national, and international levels (Confraria et al., 2024; Hartley et al., 2020; IPCC, 2023; United Nations, 2015).

b) Standardisation of data: These organisations develop universally recognised standards to ensure the comparability of data across different regions and frameworks. By promoting common methodologies, terminologies, and protocols, they facilitate cross-border data analysis and interpretation. This standardisation enhances the reliability, impartiality, and validity of statistical findings in scientific research and policymaking (Murphy and Yates, 2009; Zapp, 2021; Peltola et al., 2022;). The provision of quality data is essential for tracking advancements, assessing outcomes, and serves as a fundamental instrument for effective governance, empowering individuals to scrutinise governmental actions and actively engage in policy development endeavours (World Bank, 2018)

c) Monitoring and evaluation: In the context of evaluating policies and programmes these organisations monitor performance indicators in certain regions or actors across different dimensions such as human development (UNDP, 2024), sustainable development (Sachs et al., 2023), innovation (WIPO et al., 2023) or health (WHO, 2024). This allows to assess progress towards policy targets and benchmarking to set incentives for further developments. For example, the World Bank's Independent Evaluation Group evaluations of the Bank's projects and programmes to verify that they meet their objectives and deliver value for money (World Bank, 2021); or the recent ex-post evaluation of Horizon 2020, the European framework programme for research

² Zapp (2017) finds that the JRC to be the second most productive intergovernmental research institution worldwide during 2010-2015 as measured by publications count in Scopus.

³ A well-known exception is a report by (Doemeland and Trevino, 2014) that found that 31% of the reports published by the World Bank in 2008-2012 were never downloaded, and 87% were never cited.

covering the period 2014-2020 (European Commission, 2024). This function is vital for understanding whether policy targets are producing results, ensuring comparison exercises, and hence continuous improvement of policy interventions.

In summary, the activities of international organisations in the science-policy interface spearhead a multifaceted approach that includes formulating new targets, standardising efforts towards data collection, fostering innovation, cooperation, and evidence-based decision-making on a regional or global scale. Our focus in this paper is on assessing the take up of a policy document (the Scoreboard), from an international organisation (EC) on both, the policy and scientific communities. Thereby we aim to reflect on the role of scientized international organisations and their impact on science and policy agendas through knowledge production and data provision (Ravallion and Wagstaff, 2012; Zapp, 2021).

2.2 The genesis of the Scoreboard and its political background

R&D efforts by private and public actors have long been recognised as central to growth, productivity, and competitiveness (Griliches, 1979; Romer, 1990; Schumpeter, 1942). However, prior to the establishment of the Scoreboard, there was no systematic collection of publicly available micro-data for a large sample of top R&D investors that specifically accounted for firms' own financial resources invested in R&D. Moreover, there was no collection of such micro-data with an additional focus on the top EU corporate R&D investors⁴.

Given the central role of R&D as a policy field and the lack of internationally comparable data on major corporate R&D investors worldwide, the EU Industrial R&D Investment Scoreboard was established by the European Commission in 2004. Its purpose was to monitor the R&D activities of innovation leaders, to enable industries to benchmark their performance against their peers, and to provide policy recommendations for the EU based on its findings. Even 20 years later, there are few other initiatives that monitor R&D investments by firms, and none with the coverage and time series length of the Scoreboard. This makes it a unique contribution provided by the JRC of the European Commission.⁵

The need for a new data source became particularly pressing after the specification of an R&D intensity target in 2002, which built on the Lisbon Strategy of 2000. In 2002, the EU Council in Barcelona stated that the EU should spend 3% of GDP on R&D by 2010 ("Barcelona Target"), with two-thirds of this investment coming from the private sector.⁶ This target was set because the EU was not performing at the same level as its main competing economies at the time, notably the US and Japan. In 2002, only 1.9% of EU-GDP was invested in R&D, compared to 2.7% in Japan and 2.9% in the US. Within this overall figure, the EU business sector R&D accounted for 1.3% of GDP, compared to 2.3% in Japan and 1.9% in the US. The comparative analysis of R&D investment drove

⁴ For example, the UK R&D Scoreboard (issued up to 2009 by the UK Department of Trade and Industry - DTI, and the last edition(s) by the UK Department for Business, Innovation & Skills -BIS) was the precursor of the EU R&D Scoreboard: The last UK Scoreboard edition ranked the top 1000 UK and the top 1000 international companies by R&D investment within industry sectors.

⁵ To our knowledge, comparable initiatives comprise fDi Intelligence's collection of the world's top 100 innovation leaders (https://www.fdiintelligence.com/content/feature/global-innovation-leaders-2022-edition-82527), incorporated in 2020, whose sample is based on the Scoreboard, the "Global Innovation 1000 study" by PWC, published annually between 2005 and 2018, however with a break in the time series in 2014 (https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html), and more recently, also the OECD embarked on a quarterly monitoring of the R&D investments disclosed by the top 50 companies from the Scoreboard (OECD SwiFTBERD <u>https://www.oecd.org/en/data/datasets/short-term-financial-tracker-of-business-rd.html</u>).

⁶ To reach the 3% of GDP objective by 2010, research investment was expected to grow at an average rate of 8% per year, shared between a 6% growth rate for public expenditure and a 9% growth rate for private investment (<u>Investing in European Research - The 3%</u> <u>objective: brief history (europa.eu)</u>)

to the conclusion that the EU suffered from an 'R&D intensity gap' (European Commission, 2003a; Sheehan and Wyckoff, 2003).

To address this gap, the EC issued an "Action Plan" (European Commission, 2003a) in 2003, which aimed to "*set up an industrial research monitoring activity, including a score-board to analyse trends and facilitate benchmarking of research investment and research management practices between firms, building on experience in Member States (Implementation: Commission support; first report early 2005)*". Based on this mandate, the first edition of the Scoreboard was issued in December 2004. Clearly, one of its purposes was to permit benchmarking of R&D investment efforts between competing firms, sectors, and economies. Since the data for the Scoreboard comes directly from the audited accounts of firms, it could be provided more timely than national statistics.

Over time, the Scoreboard expanded its scope. From 2012 onwards, it reports R&D investment and other selected financial indicators of the 2500 largest companies in the world in terms of R&D investment, plus an additional sample of the largest 1000 R&D-investing companies from the EU.⁷

The data for the ranking come from the audited company accounts of the previous financial year, provided they follow a recognised international accounting standard.⁸ Due to different accounting practices worldwide, the Scoreboard includes accounts ending within a range of six months before or after the end of a specific financial year. Overall, around 70% of company accounts cover a 12-month period from January to December.

The R&D investment in the Scoreboard follows the definition of the Frascati Manual (OECD, 2015). It is defined as the cash investment funded by the companies themselves and excludes R&D undertaken under contract for customers (governments or other companies). It also excludes the companies' share of any associated company or joint venture R&D investment when disclosed but includes research contracted out to other companies or public research organisations. Where part or all the R&D costs have been capitalised, the additions to the appropriate intangible assets are included, and any amortization is eliminated. To avoid double counting, the consolidated group accounts of the ultimate parent company are used. If the consolidated group accounts are not available, subsidiaries are included. In the case of a demerger, the full history of the continuing entity is included, while in the case of an acquisition or merger, pro forma figures for the year of acquisition are used.

Companies are allocated to the country of their registered headquarters, which can be different from the operational or R&D headquarters. Therefore, the Scoreboard data presents an indicator of a corporation's global financial commitment to R&D rather than country-level statistical aggregates. This firm-level perspective complements national and supranational R&D data collection efforts, which focus on country-level aggregates such as business enterprise R&D expenditure (BERD). BERD refers to all R&D activities performed by businesses within a particular territory, regardless of the location of the business's headquarters or the sources of finance. The distinction between Scoreboard and BERD data can be summarised as 'global corporate funding' versus 'activity within a geographical area'.

With these features, the Scoreboard constitutes a unique and valuable addition to the data provided by national statistical offices, Eurostat, or the OECD (Moncada-Paternò-Castello et al., 2010). The

⁷ In the first Scoreboard the sample size was 500 EU and 500 non-EU companies, in 2005 it expanded to the top 700 EU and top 700 non-EU companies, from 2006 to 2011 it covered the top 1000 EU and top 1000 non-EU companies, in 2012 the non-EU sample increased to 1500 companies, in 2013 it expanded to the top 2000 non-EU, and since 2014 the Scoreboard covers the top 1000 R&D investing companies from the EU plus the top 2500 non-EU.

⁸ International Financial Reporting Standards or United States Generally Accepted Accounting Principles.

firm-level data and the analyses provided by the Scoreboard are meant to be used complementarily to other analytical information or data sources on R&D (European Commission, 2003b)⁹. Since its launch, the Scoreboard was published every year and celebrated its 20th anniversary in 2023, making it the longest-running periodic publication providing internationally comparable firm-level R&D data. As the Scoreboard has been set for use by different actors (policy-makers, firms, economic and financial analysts, and academia), after 20 years of its release, we conducted the first analysis of its use and its contribution to advancing collective knowledge in science and policy.

⁹ Moncada-Paternò-Castello et al. (2020) recommend that policymakers, and economic, financial and scientific analysts also from business sectors use data from complementary sources (e.g. Scoreboard, ANBERD, EU-KLEMS, FACTS, PASTAT), considering the appropriateness to the analytical aim as well as the robustness and limitations of the data.

3 Data and Methods

3.1 Data

To evaluate the influence of the Scoreboard in science and policy, we analyse documents that cite any of the Scoreboard reports or data in scientific publications (articles and reviews) indexed in the Web of Science Core Collection (WoS) and policy documents indexed in Overton.¹⁰

Our approach involves several steps to obtain a final set of documents citing the Scoreboard. In Figure 1 we schematise our search strategy for scientific publications and policy documents.





For scientific publications, we searched every edition of the report from 2004 to 2022, as well as for citations of the Scoreboard without specified year, on Google Scholar (GS) and Dimensions, and identified documents citing each edition until December 2023. Subsequently, we extracted the titles, publication names (e.g., journals), and publication years of all documents that cited a specific edition. Although GS offers a more comprehensive picture of the number of citations received by a certain document (compared to Dimensions, WoS and Scopus), it has also been criticised for harvesting citations from everywhere on the web, which can include duplicates or manipulations (López-Cózar et al., 2014). Therefore, our third step was to cross and integrate our results with WoS to only include article and reviews in peer-reviewed journals. Finally, we chose to select publications only in English. Additionally, we supplemented our GS- and Dimensions-derived list with other publications citing Scoreboard reports by searching for "Industrial R&D Investment Scoreboard" in all fields in Lens, WoS and Scopus. These searches in different indexing systems led to several duplicates that we eliminated at a later stage. We also made sure that the documents retrieved

¹⁰ The Web of Science Core Collection was chosen due to its comprehensive coverage of peer-reviewed journals across a wide range of disciplines, ensuring a robust and reliable dataset for bibliometric analysis. Overton was selected for sourcing policy documents because it offers the most extensive collection of policy-related literature from government, think tanks, and non-governmental organisations globally.

cited any version of the Scoreboard, and not any other different Scoreboards (e.g. the European Innovation Scoreboard).

After consolidating this final list of 347 publications in WoS (articles and reviews) citing the Scoreboards from 2004 to 2023, we downloaded and analysed all bibliometric information retrieved from WoS and conducted a citation content analysis.

For the analysis of the uptake of the Scoreboard in policy documents we collected data via "Overton", a platform that screens webpages for policy documents, and links these documents to each other, scientific publications, authors and topics. Overton aims at identifying not only policy or legislation itself, but the material that has influenced it, such as academic literature, technical reports or policy briefs. This allows expanding citation analyses beyond the academic realm, and analyse research influencing policy.¹¹

Overton defines policy documents as "documents written primarily for or by policymakers that are published by a policy focused source". In 2019, it started to collect policy documents and their citations on webpages of governments and official bodies, intergovernmental organisations, nongovernmental organisations and think tanks. Thereby the platform aims at covering documents from organisations that explicitly focus at influencing policy with the knowledge they produce (Szomszor and Adie, 2022).

By April 2024, Overton indexed over 12 million documents from more than 43,000 national and international sources including governments, think tanks, intergovernmental organisations, and charities. The data was retrieved via the same search process as described for GS on 10 April 2024. The search resulted in 1978 documents, which, after removing duplicates (e.g., due to publication of the same document on different websites, in different languages, with different titles), deleting wrong citations, references to documents that could not be checked (if no document was available), and documents such as the Scoreboard itself, releases of preliminary insights, or the annual activity reports of the JRC, resulted in 711 different policy documents for analysis. For consistency with the scientific citation analysis, we restrict our sample to the Scoreboard editions 2004-2022 and the citation window until end of 2023, leaving us with 658 policy documents.

For every document we manually collected information on the year of publication (which can differ from the year of publication on the source webpage), the Scoreboard vintage(s) cited, and, if possible, the institutions and authors that produced the policy document. In many cases the institution that published a policy document differs from the one that actually produced the content (see footnote 15 for an example).

3.2 Analysis

Our analysis consists of three segments. In Section 4.1, we utilise bibliometric analysis and descriptive statistics to examine citations to the Scoreboard in both scientific publications and policy documents. We analyse time trends, top actors (institutions), collaboration networks, and explore more frequent topics and areas of influence. In Section 4.2, we conduct a citation content analysis on scientific publications to examine in more detail how the Scoreboard has been cited. Finally, in section 4.3, we present the results of a document analysis of selected EU policy documents that

¹¹ We also looked up the EU Industrial R&D Investment Scoreboard on <u>www.altmetric.com</u>, but found only few results. Not each Scoreboard edition could be identified, and in total only 76 mentions were collected and 27 outputs tracked. Of these, 18 mentions refer to 13 policy documents, all of them are covered by Overton. We therefore confined our research to Overton only.

cited the Scoreboard aimed at investigating if and how the Scoreboard insights influenced the policy narrative in EU policy making.

3.2.1 Time trends

Our analysis starts by looking at the evolution of citations to the different Scoreboard editions both in terms of the citing documents and the vintages of the Scoreboard. We compare the most frequently cited Scoreboards in science and policy, and calculate average citation windows to compare if citations in policy documents appear more rapidly than in scientific publications. To determine if there is a statistically significant difference in the average citation window between the two types of documents, we perform a two-sample t-test using Stata.

3.2.2 Institutional representation and collaboration

One of our objectives is to identify the main actors that cited the Scoreboard and to characterise their main collaborative linkages. To this end, for scientific publications, we build a network of institutional research collaboration (co-authorship) based on information on the institutional affiliation using the full counting method (e.g., a publication done in collaboration between researchers in institutions from Spain and Italy would be credited to both institutions). To address variations in institutional affiliations, we employed the 'organisation enhanced' function available in WoS to aggregate institutional name variations of the scientific publications. The resulting network graph developed using Gephi¹² software represents institutions producing at least 3 publications citing the Scoreboard (core). In this graph, each node represents an institution, with node size indicating the number of publications (ranging from 3 to 17), and edge size reflecting the intensity of co-authorship (ranging from 2 to 6).¹³

For policy documents, the network analyses are based on the *Statnet: Tools for the Statistical Modeling of Network Data package* for R.¹⁴ One important specificity for our research concerns the retrieval of policy documents from the EU, the institutions producing most of the policy documents citing the Scoreboard. As noted in Bornmann et al. (2022), Overton uses the "Publications Office of the European Union" as an aggregate for many different EU institutions. The Publications Office is the "bookshop" of the EU, responsible for publishing, distributing, and preserving the official publications of the EU institutions. However, publications from the JRC, different Directorate-Generals (DG) of the EC, or other EU institutions are uploaded on their respective websites *and* the Publicates for EU documents. Also, national governments publish EU policy documents. Moreover, Overton assigns ownership and source country of the policy documents based on the retrieval websites, so that the data cleaning process unavoidably affects the composition in terms of institutions, organisations, and countries.¹⁵

After cleaning the original Overton data download for duplicates, we manually changed the "Publications Office of the European Union" to either JRC, other Directorate General from the European Commission (EC), or other EU institution that produced or commissioned the document.

¹² <u>https://gephi.org/</u>

¹³ Two institutions were included in the collaboration network that have only 2 publications citing the Scoreboard because those publications are in collaboration with an institution from the core (>2).

¹⁴ https://statnet.org/

¹⁵ For instance, the paper "Business groups as hierarchies of firms: determinants of vertical integration and performance" was authored by Armando Rungi and Carlo Altomonte and published as a European Central Bank (ECB) working paper. The authors themselves were not affiliated with the ECB, but instead with two different universities. Overton collected this publication 3 times – once for the ECB, once via the EU Publications Office, and once via another (non-EU) institution that published the paper on its website.

This issue also affects the document retrieval from "EUR-Lex", an online database providing access to legal information related to the EU. EUR-Lex contains the Official Journal of the European Union, legislation, preparatory acts, and other legal and legislative documents. However, not every document on EUR-Lex is legislation, and EUR-Lex itself does not produce any documents, making it incomparable with other source titles. In our analysis, all EUR-Lex documents are *European Commission Communications (COMs)* or *European Commission Staff Working Documents (SWDs)*. *COMs* are policy documents from the EC outlining its priorities, strategies, and initiatives, while SWDs provide additional information, detailed analysis, technical information, or background data supporting the *COMs* or legislative proposals.

*SWD*s are often published as stand-alone documents, even if they are linked to *COMs*. They can be accessed and read independently. These types of documents are highly relevant for EU policy making, as they accompany a position or a proposal of the EC to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The *COMs* and *SWDs* are always authored by the EC, usually with one DG leading, and coordinating input from other DGs. Moreover, they usually do not provide references to the contributors of its text. Overton sources *COMs/SWDs* from all institutions to which they are addressed to, leading to around 4 times more policy documents than there actually are; many of these documents were also published on websites of EU Member States, creating even more duplicates. The duplicates were deleted and all remaining *COMs/SWDs* were manually assigned to the EC. In total, 24 *SWDs* (two of them are annexes to *COMs*) and 3 *COMs* cited the Scoreboard, and, in line with the renewed interest in industrial policy, all *SWDs* were published between 2017 and 2023, citing Scoreboard vintages 2015-2022 (2013-2020 for the *COMs*).

A similar simplification was applied to the United Nations (UN) documents. We assigned all 12 documents published by United Nations' organisations (UNCTAD, UNIDO, UN CEPAL, etc.) to the UN.

3.2.3 Research and policy areas and topics of influence

In section 4.3 (Areas and topics of influence), for scientific publications, we analyse the top journals where publications citing the Scoreboard appear, top disciplines and keywords. For research areas we use the 326 CWTS Meso Citation Topics¹⁶ proposed by WoS. They are a document-level classification schema that represent groups of publications related to one another via citation relations. For keywords we perform a co-occurrence analysis using VOSviewer¹⁷ (van Eck and Waltman, 2020). We only included keywords (author + keywords plus) that appear in more than two publications (526 out of 1834 keywords), and we used the LinLog/modularity normalisation method. Additionally, we calculated the average publication year for each keyword to identify emerging topics within our dataset. In discussing our findings, we also highlight highly cited articles that reference the Scoreboard, elucidating main themes and research questions.

The policy documents are tagged to 3 keywords each (526 different tags in total). These tags are not the keywords that authors or the publishing institutions use, but generated by Overton. Overton defines topics (keywords) as the main themes of a document and identifies them by analysing the phrases and entities in the document and comparing them to the Wikipedia pages that have the most in common. Finally, the titles of Wikipedia pages with most overlap with the policy document are chosen as topics.

¹⁶ <u>https://clarivate.com/blog/introducing-citation-topics/</u>

¹⁷ VOSviewer facilitates the extraction of relevant topics from text data by analysing the co-occurrence of keywords, which in turn produces maps showing coherent clusters that allow us to understand what the major topics are and how they are interlinked.

Before performing our co-occurrence analysis, we normalise the keywords for both scientific publications and policy documents. This was done using the text facet functions of OpenRefine¹⁸ and manual methods to unify terms with the same meaning under one keyword (e.g., "research and development" and "R&D", "panel" and "panel-data", "patent" and "patents"). We then create an overlay map to compare the frequency of keywords in both samples. To identify keywords specific to either scientific publications or policy documents, we use a Log-Odds Ratio with Informative Dirichlet Prior. This metric allows to compare the importance of keywords that appear frequently in one type of document but not in the other, while handling zeros effectively. The Log-Odds Ratio:

$$LOR_{i} = log\left(\frac{(TF_{i1} + \alpha)/(N_{1} + \alpha \cdot V)}{(TF_{i2} + \alpha)/(N_{2} + \alpha \cdot V)}\right)$$

Where TF is the total frequency of keyword i in policy documents (1) and scientific publications (2). N is the total number of keywords in both groups. V the total number of unique keywords, and a a prior value to provide stability to the log-odds ratio (=1). This approach helps us pinpoint keywords that are context-specific, allowing for a more nuanced understanding of the areas and topics influenced by the Scoreboard.

3.2.4 Citation content analysis

In our work we also perform in-text examination of citations from scientific publications to the Scoreboard to understand how it was cited. This analysis focuses on how the Scoreboard data was utilised and which specific findings from the Scoreboard were cited. Through in-text examination we scrutinised each citation to extract contextual information, including the specific sections, statements, or findings that are referenced by authors (Anderson and Lemken, 2023). This approach provides a nuanced understanding of how the Scoreboard is used across various scholarly contexts.

Garfield (1962) published the probably earliest paper listing possible motivations of citers. Since then, various schemes have been proposed to classify functions of and reasons for citations (Garzone and Mercer, 2000; Nishikawa, 2023; Stremersch et al., 2015; Tahamtan and Bornmann, 2018). In a comprehensive literature review of citing behaviour, Bornmann and Daniel (2008) summarised 8 main types of citation in a unified typology: affirmational (citing work confirms or is strongly influenced by cited work); assumptive (citing work refers to assumed knowledge that is general/specific background); conceptual (use of definitions, concepts, or theories of cited work); contrastive (citing work contrasts between the current work and cited work); methodological (use of materials, equipment, practical techniques, or tools of cited work); negational (citing work disputes some aspects of cited work, corrects/questions cited work, negatively evaluates cited work); perfunctory (citing work does not really uses data or findings of cited work); and citations of the persuasive type (cited work is cited in a "ceremonial fashion"). In Table 1, we adapt and simplify this typology in three "Insights" categories (I), four "Data" citation categories related to usage of the SB data (D) and two "Other" categories:

¹⁸ <u>https://openrefine.org/</u>

Table 1. Citation categories

Category	Code	Description
	I_Background	Cites the Scoreboard to provide background or context based on previous studies.
Insights	I_Application	Cites the Scoreboard to use or compare its findings, methods, or concepts.
	I_Negative	Cites the Scoreboard to criticise or reject its findings, methods, or concepts.
	D_1	Uses a specific dataset or list of firms from the Scoreboard.
Data	D_Multiple	Uses multiple datasets from the Scoreboard (e.g., for creating a panel).
	D_Combined	Combines Scoreboard data with other datasets.
	D_Combined_Patent	Combines Scoreboard data with patent datasets.
Other	Null	Cites the Scoreboard indirectly, without really using its data or findings.
	Vintage	Refers to the year the R&D Scoreboard was published.

We created additional variables (Null and Vintage) to capture perfunctory citations and the publication year of the cited Scoreboard edition.¹⁹ By reading each article citing the Scoreboard, we also identified the types of data combined with Scoreboard data (e.g., patents, company data) and the sources of these additional datasets.

Manual in-text citation categorisation presents several challenges. It depends on human judgment, which can introduce subjectivity and potential bias. Some citations may not fit neatly into predefined categories, and different analysts might interpret citations differently, leading to inconsistencies. To mitigate these issues, we thoroughly discussed category definitions based on relevant literature before starting the categorisation. Additionally, each citation was reviewed independently by two authors, and any discrepancies were resolved through discussion to ensure consistency.

To determine if publications citing the Scoreboard within certain categories receive more citations than others, we use regression analysis. The dependent variable is the number of citations received by each publication until 2023. Given that the outcome variable is count data (ranging from 0 to 246) and exhibits a Poisson distribution (right-skewed), a Poisson regression model would typically be suitable. However, Poisson regression is inefficient for overdispersed data, where the variance exceeds the mean (Cameron and Trivedi, 2013). Overdispersion in the data leads to underestimated standard errors, highly significant parameters, and consequently, inefficient estimates.

Since our dependent variable is overdispersed (see Table 7), we used negative binomial regression. The probability density function of the negative binomial model is:

¹⁹ If several Scoreboard vintages were cited, we choose the latest version. If no indications of vintage were available, we choose the latest version before publication submission date (as indicated in the respective paper).

$$f(y_i) = \frac{\Gamma(y_i + \theta)}{\Gamma(\theta) * y_i!} * \frac{\mu_i^{y_i} * \theta^{\theta}}{(\mu_i + \theta)^{y_i + \theta}}$$

where which Γ denotes the gamma function and θ is the model's dispersion parameter, which must also be estimated in the negative binomial regression. The parametrisation of μ_i is a function of the regressors of interest that follows a log-linear specification:

$$ln(\mu_{i}) = \beta_{0} + \beta_{1}x_{1i} + \beta_{2}x_{2i} + \dots + \beta_{k}x_{ki}$$

We relate our dependent variable to the following regressors: (1) usage of Scoreboard (SB) data, (2) data combination, (3) usage of patent data, and (4) number of authors. Our model also controls for publication year, as more recent publications have had less time to accumulate citations. The sign of the estimated parameters β in the regression indicates whether the dependent variable increases with the regressor.

Additionally, we conduct an OLS regression analysis as a robustness check. However, the OLS results should be interpreted cautiously because this model is not a good fit for our data, which is not normally distributed, and likely exhibits a non-linear relationship between the predictors and the dependent variable.

4 Results

4.1 Time Trends

Since its inception in 2004, the Scoreboard has garnered significant attention from both the scientific and policy communities. By December 2023, it had been cited in 347 scientific publications and 658 policy documents. In this section, we present citation trends using two perspectives: the number of citations received by each Scoreboard edition (vintage) and the number of documents citing the Scoreboard each year (year of publication).

Figure 2 shows the number of scientific publications and policy documents citing each Scoreboard edition (vintage). The 2013 vintage received the most citations (52 policy documents and 34 scientific publications); the 2011 vintage had the highest number of scientific citations (37), and the 2019 and 2013 vintages are cited most frequently in policy documents (52 each). Over the years, the ratio of policy documents to scientific publications citing each Scoreboard has steadily increased. The most recent three editions have almost three times more policy than scientific citations. Notably, the 2004 and 2005 editions are the only ones cited more by scientific publications than policy documents, likely due to the novelty of the data for the scientific community at that time.



Figure 2. Number of scientific publications and policy reports citing each Scoreboard, by vintage

Source: own elaboration based on WoS and Overton

It is essential to note two aspects when interpreting Figure 2. First, the most recent Scoreboard editions have had less time to accumulate citations. For example, the 2021 edition had only two years for citations, compared to the 2013 edition's ten years. Second, the average citation window for policy documents is much shorter (1.9 years) than for scientific publications (4.4 years). Around 93% of policy documents cite the Scoreboard within 3 years of publication, while only 50% of scientific publications do so in the same period, and 22 scientific publications citing it more than ten

years after publication.²⁰ We performed a t-test to test the hypothesis that the average citation window of policy documents is shorter than that for scientific publications. The results indicate a statistically significant difference between the citation windows of policy documents and scientific publications (p-value < 0.01). This difference is likely due to the quick policy monitoring nature of the Scoreboard, and the longer publication process in scientific research, especially in fields like economics and business (Huisman and Smits, 2017).

We also found evidence of a shortening of the interval between Scoreboard publication and policy document citation. While the first 3 vintages were on average cited 2.5 years after the publication, this time difference became smaller and amounted to 2.2 years for the Scoreboard editions 2007-2009 and 2010-2012, 2 years for the Scoreboards 2013-2015, 1.6 years for the vintages 2016-2018, and 1.5 years for the 3-year window 2019-2021 (see Figure A.1 in the appendix for the citation dynamics of the different Scoreboard vintages). Both, the increasing number of citations over time and the shorter time elapsed between publication and citation suggest that policy stakeholders are aware of the Scoreboard's annual December publication date and find its content immediately relevant.

Another reason might be that the Scoreboard provides data on R&D investments with a shorter time lag than official R&D statistics.²¹ While the Scoreboard R&D data is not directly comparable to BERD data (Moncada-Paternò-Castello et al., 2020), the rapid publication of the data compared to official statistical allows for early insights into global corporate R&D investment trends.

Additionally, 91 policy documents (13.8% of the sample) cited more than one Scoreboard vintage. These documents often compare the development of a country, region, or sector over time, as seen, e.g. in the European Investment Bank's investment reports.²² This practice of citing multiple vintages leads to an increase in the average time between the publication of a policy document and the cited Scoreboard vintage (see Figure A.1. in the appendix).

Finally, in Figure 3, we perform a similar analysis comparing citation patterns of policy documents to scientific publications, but this time we use the citing document publication year for the analysis. We observe that for both, scientific publications and policy documents, the first reference to the Scoreboard occurred in 2006, two years after the first edition was published. Since then, the number of scientific publications referencing the Scoreboard has steadily risen, starting from 2 citations in 2006 and peaking at 42 citations in 2023, indicating a relative increase in scientific impact in comparison with policy impact. The only period with a slight decline in the trend was during 2020-2021, the period of the COVID-19 crisis. For policy documents, the citation peaks were achieved in 2013 when 59 policy documents referenced different editions of the Scoreboard. Since then, the number of citations by policy documents per year has been consistently between 40 and 55.²³

²⁰ See Table A.1 in the appendix for specific citation counts for each edition.

²¹ The Scoreboard publishes the companies' R&D figures from the previous financial year (e.g., the Scoreboard 2022 presents the data from the 2021 financial accounts).

²² https://www.eib.org/en/publications-research/economics/research/investment-report

²³ Splitting up the 18 years since the first citation in 3-year citation windows after publication of the Scoreboard shows a substantial increase in citations, from on average 8 policy citations per year (2006-2008), to 26 (2009-2011), 39 (2012-2014), 48 in 2015-2017, 45.7 in 2018-2020, and 48 for the period January 2021 to December 2023. This shows that the relevance of the Scoreboard for policy increased with time, and/or that the awareness of the Scoreboard among authors of policy documents grew.



Figure 3. Number of scientific publications and policy documents citing the Scoreboard, by year of publication

Overall, the Scoreboard has gained significant attention from both the scientific and policy communities. The number of citations varies by edition (vintage) and publication year, with the 2013 edition receiving the most citations until now. Most policy documents cite the Scoreboard within three years of publication, while scientific publications tend to have a longer citation window. Over time, the interval between Scoreboard publication and citation by policy documents has shortened, highlighting the Scoreboard's relevance to policymakers thanks to the timely provision of corporate R&D investment data. At the same time, the ratio of scientific publication relative to policy documents citations has steadily increased, especially for recent editions, indicating a growing recognition from the scientific community.

4.2 Institutional representation and collaboration

In terms of actors, the Scoreboard has been cited by researchers from over 300 different "research" institutions, and 115 "policy" institutions. This section explores the institutions that have cited the Scoreboard in scientific publications and those involved in producing policy documents.

4.2.1 Scientific publications collaboration network

Figure 4 illustrates the collaborative network among institutions with researchers who have cited the Scoreboard in their scientific publications (with more than 2 publications). The size of each node reflects the frequency per institution, ranging from a maximum of 26 publications (University of Salerno) to a minimum of 4. The width of the edges indicates the number of co-authorships, with a maximum of 11 (shared by KU Leuven and Maastricht University) and a minimum of 2.

The University of Salerno (notably featuring the most prolific author: Luigi Aldieri) emerges as the institution with the highest number of publications citing the Scoreboard, accounting for approximately 7% (26) of the sample. The JRC also appears as an important player (21), standing

Source: own elaboration based on WoS and Overton

out for having the most collaborators (7) within this network, suggesting active collaboration between researchers directly or indirectly involved in the Scoreboard and other institutions. Here, it is important to note that many contributors to past Scoreboard editions have since left the team and may have cited the report in collaboration with JRC colleagues, under their new affiliations.

KU Leuven (20) is the other institution with more than 5% of the sample and has the two most intense (triadic) collaboration with Maastricht University (11) and Hasselt University (10). The other institutions with over 5 publications include the Catholic University of the Sacred Heart, Université Libre de Bruxelles, University of Lund, Universidade de Lisboa and ETH Zurich.

The distinct cluster of Belgian (yellow) and Dutch (orange) institutions is prominent not only for its high publication count, but also for substantial collaboration within the cluster. Additionally, 6 Italian academic institutions, including the University of Salerno and Parthenope University Naples, form a separate connection from the JRC. Other research institutions from countries such as Portugal (Univ. Lisboa), France (CNRS), Spain (CSIC), Russian Federation (HSE Univ.), Slovenia (Univ. Ljubljana), Sweden (Univ. Lund), Germany (Fraunhofer Gesellschaft) each have 4 publications citing the Scoreboard, but did not co-author papers with the JRC.

Overall, the Scoreboard is cited by a diverse set of researchers from various countries, with many having direct or indirect ties to the JRC. However, it is evident that the Scoreboard is also used by scholars who do not collaborate directly with the JRC. A striking result is the lack of US, Japanese and Chinese institutions citing the Scoreboard, implying lack of awareness (or interest) by those researchers on Scoreboard data and insights.



Figure 4. Collaboration network of top institutions citing the Scoreboard in scientific publications

Source: own elaboration based on WoS

Notes: Colours represent countries; Size of nodes represent number of publications citing the Scoreboard; Size of edges represent number of co-authorships between institutions.

4.2.2 Policy documents publishing organisations

Regarding policy documents, Overton attributes authorship to the organisation/institution from which it retrieved the document. The institutions are classified in four categories – government, intergovernmental organisations (IGO), think tank and other, and are allocated to the countries/regions from which the documents were sourced (except for IGO publications). To better separate references to the Scoreboard by national/regional governments and EU institutions, we reclassified EU publications as "EU", so that "government" only refers to national/regional governments (or governmental agencies). Moreover, as the category "others" only contained 3 cases, we added these to "think tank".

From the 658 policy documents, 52.6% are retrieved from EU portals, 19.7% from think tanks, 14.7% from national or regional governments as well as governmental agencies, and 12.9% from IGOs.²⁴ Figure 5 shows how the number of policy documents per source type evolved over the period 2006-2023. Every year, between 33% and 73% of the policy documents are published by EU institutions. The number of publications from national/regional governments oscillates between one and 10 publications per year, and between one and 14 for IGOs. Towards the end of the period the number of documents produced by think tanks increases.



Figure 5. Policy documents per source type, citing period 2006-2023

Source: Overton, own elaboration. Note: IGO = Intergovernmental organisations.

We identified policy documents on webpages from 32 different countries (excluding EU and IGO). In total, 115 different organisations/institutions published policy documents using the Scoreboard – Table 2 summarises the publishing organisations in countries/regions with more than 10 documents, covering 90% of the policy documents in the analysis and 75 out of the 115 organisations/institutions.

In 12 countries only governmental institutions published policy documents citing the Scoreboard, while in 6 countries it was only think tanks. In 11 countries the policy documents were produced by

²⁴ The original classification of Overton gives the following result: 67.3% government, 19.3% think tanks, 12.9% IGOs, and 0.5% "others".

governmental agencies and think tanks. The share of think tanks was particularly high in Belgium, the UK and the US. Belgium hosts several prominent think tanks which are responsible for 24 of the 27 Belgian policy documents, with the most important being Bruegel (12 publications), ECIPE (5 publications) and Business Europe (4 publications). For the UK we could identify 33 policy documents out of which 24 are published by think tanks, the most important ones being Technopolis with 22 publications (note that Technopolis is involved in 15 joint publications with other institutions, of which 13 were retrieved from websites other than the UK), followed by the Chatham House with 3. In the US, 25 of the 27 policy documents were produced by think tanks; the most intense US user of the Scoreboard was the Information Technology & Innovation Foundation with 8 publications, followed by the RAND Corporation and the Atlantic Council with 4 policy documents each.

Source country	n	Publishing organisations	Share pub
EU	346	European Commission; European Economic and Social Committee; Eurofound; European Central Bank; European Investment Bank; European Parliament; Eurostat	52.6%
IGO	85	Asian Development Bank; International Energy Agency; International Labour Organisation; OECD; United Nations; World Bank; World Economic Forum; World Health Organisation; World Intellectual Property Organisation	12.9%
Germany	34	Government: Baden-Wüerttemberg.de; EFI; Niedersachsen; Landesregierung Nordrhein-Westfalen; City of Berlin; Umwelt Bundesamt Think tank: DIW; Friedrich-Ebert-Stiftung; Deutsches Institut für Entwicklungspolitik; Ifo Institute; IZA Institute of Labor Economics; Kiel Institute for the World Economy; Konrad Adenauer Stiftung; Rosa- Luxemburg-Stiftung	5.2%
UK	33	Government: The UK Government; UK Parliament Select Committee Publications Think tank: Centre for Cities; LSE Consulting; Centre for European Reform; Chatham House; ESRC Centre for Climate Change Economics and Policy; Technopolis; Global Canopy; Higher Education Policy Institute; Institute for Fiscal Studies; Royal Society; NESTA	5%
Belgium	27	Government: Federal Planning Bureau; Government of Flanders Think tank: Bruegel; Business Europe; CEPS; Digital Europe; ECIPE; Science Europe	4.1%
USA	27	Government: House Committees; Senate Committees Think tank: Atlantic Council; Belfer Center; Boston Consulting Group; Brookings Institution; Carnegie Endowment for International Peace; Center for a New American Security; Center for Automotive Research; Center for Transatlantic Relations; Information Technology & Innovation Foundation; McKinsey Global Institute; RAND Corporation	4.1%
France	14	Government: Cour des Comptes; French Government Ministries; La Documentation Française Think tank: CGIAR; International Confederation of Societies of Authors and Composers CISAC; Institut Jacques Delors	2.1%
Japan	12	Government: Bank of Japan; Government of Japan	1.8%
Spain	11	Government: Boletín Oficial del Estado; Generalitat de Catalunya; Government of Spain	1.7%

Table 2. Top regions/countries and organisations using the Scoreboard in policy documents

Source: Overton, own elaboration.

Note: EU institutions and United Nations were harmonised as described in the text below. IGO = Intergovernmental organisations. All EU publications are government (transformed to EU), all IGO publications fall under the category IGO. The names of the publishing institutions/organisations were taken from Overton.

As mentioned above, the country allocation relates to the website's host country from which Overton retrieved the policy document. If a policy document was co-produced by several organisations/institutions from different countries (or IGOs), the document is assigned to one country only. While this leads to a small bias as close to 20% of the policy documents were coauthored by different institutions/organisations, it does not alter the main conclusions, namely that EU institutions and IGOs are the most frequent users of the Scoreboard for their policy documents, and that there appears an increasing trend in the number of think tanks (and consultancies) referencing the Scoreboard in their publications.

When studying the publications in our sample, we observe two potential roles of think tanks: one relates to their role as contractors for specific tasks such as external policy evaluation (e.g., EU Framework programmes²⁵), and second to their role in assessing policies and presenting opinions on policies for their relevant stakeholders/audience, i.e. those actors who they want to influence, ammunition their arguments, or from which they want to attract attention. Examples are publications on e.g., geopolitics/international affairs (Atlantic Council, Centre for Transatlantic Relations, Chatham House), EU policies (e.g., Bruegel, ECIPE, Institut Jacques Delors), sectoral analyses, competitiveness and innovation (e.g., Business Europe, McKinsey), science, research and innovation (e.g. Praxis, RAND), economic impact analyses (e.g., Copenhagen Economics).

The list of think tanks in our sample relates well to the second and third categories of the think tank typology summarised by Pautz (2020): the first type labelled as "universities without students" or "academic think-tank" that aims at objectivity and non-partisanship, the second type of "contract research organization" that conducts mostly commissioned research and portrays itself as technocratic and nonpartisan, and the third type, the "advocacy think-tank", which actively seeks to influence policy debates.

Overall, the increase of think tank publications citing the Scoreboard might relate to the general rise in interest in industrial policy, in particular the conjunction of R&D and geopolitics, often focussing on specific sectors (such as ICT/big tech, pharma and biotech, as well as automotive). Both, the firm-level perspective as well as the regional comparison provided by the Scoreboard appears as useful for think tanks to frame, motivate and underpin their arguments.

As described above, Overton assigns the authorship of the policy documents to the institutions/organisations that publish the document. However, this does not necessarily coincide with those who actually produced the document. To address this, we manually collected author affiliations from each document.

In total, the 658 policy documents were produced by authors from 360 different organisations; 530 policy documents were produced by one single organisation (80.5%), 9% by authors of 2 organisations, 5% by 3, 3% by 4 and 2.5% by authors from 5 up to 11 organisations. In comparison, the 347 scientific publications were produced by authors from over 300 different organisations. Specifically, 38% of these publications were produced by a single institution, 39% by two or three institutions, and 23% by more than three institutions, with a maximum of 21 institutions contributing to a single paper. This indicates that collaboration networks in scientific publications are more extensive than those in policy documents.

²⁵ These evaluation studies were mostly sourced from the websites of the programme owners (governments, EU) that commissioned the work and are therefore not classified as think tank. We agree with this allocation given that programme evaluation studies are contractual work with a clearly defined scope and evaluation questions that distinguished this work from "generic" research or opinion papers.

With 346 publications, EU institutions are the primary producers of policy documents using the Scoreboard, with 312 documents published by the EC.²⁶ The next main users are the OECD with 41 policy documents, followed by the UN with 18. The OECD employs insights and data provided by the Scoreboard since the 2006 edition, and has consistently published policy documents citing the Scoreboard almost every year since 2007, except for 2010. Other recurrent publications using the Scoreboard include the OECD Economic Surveys, the OECD Reviews of Innovation Policy, the OECD Science, Technology and Industry Outlook, or the OECD SME and Entrepreneurship Outlook. The UN incorporates the Scoreboard in period publications such as the UNESCO Science reports or the UN CEPAL reports.

The fourth largest single user of the Scoreboard is the EFI, the German Commission of Experts for Research and Innovation ("Expertenkommission Forschung und Innovation") with 16 publications. The EFI (classified as "government" by Overton, see Table 2) advises the German government and presents annual reports on research, innovation and technological performance in Germany. It also acts as a science broker by initiating, funding and publishing research relevant for their (policy) needs.

Some of the spikes in citations over time in Figure 5 are related to country reports series. The Scoreboard was cited in 30 ERAWATCH country reports produced by the JRC between 2007 and 2013, in 36 Research and Innovation report country profiles from the JRC between 2014 and 2017, as well as in the Research and innovation performance country reports written by DG R&I in 2013 and 2014. The OECD also uses the Scoreboard in its country report series, more precisely in 7 OECD Reviews of Innovation Policy published between 2013 and 2023.

The Scoreboard is also featured in several prominent periodic publications (we only look at reports that were produced at least 3 times):

- European Innovation Scoreboard (EIS) 2017-2023: since 2017, the EIS, produced by DG GROW and Maastricht University/UNU-MERIT, includes one indicator in the category "Business and Entrepreneurship" based on the Scoreboard the top R&D spending enterprises per 10 million population as an average over the previous 3 years.
- Science, research and innovation performance of the EU (EU SRIP) 2016-2024: the biannual report produced by DG R&I uses the Scoreboard in different chapters. In several SRIPs, relevant chapters were co-produced by JRC authors.
- European Investment Bank Investment Reports 2018/2019-2023/2024: The EIB investment reports use the data from the Scoreboard provides, employing various editions to construct a panel dataset.
- WIPO Global Innovation Index 2015-2024 (GII): The World Intellectual Property Organisation (WIPO) uses the list of 2500 top R&D investors for their data gathering efforts. It derives the indicator "Global corporate R&D investors, top 3", which is the average expenditure of a country's top three companies on R&D in million USD.
- The UN CEPAL Foreign Direct Investment in Latin America and the Caribbean 2010, 2017, 2018, 2020 reports: The UN CEPAL uses insights and data from the Scoreboard to frame its argumentation in 4 reports.

²⁶ Please note that a number of EC policy citations could be included by JRC staff involved with the Scoreboard, given the collaborative nature of work within EU Institutions

• Clean Energy Technology Observatory 2022-2023: As part of the Green Deal, the JRC started this publication series focusing on technologies supporting the green and digital transition. The Scoreboard contributes to the analysis on clean technologies patenting. So far, 6 reports use insights and data from the Scoreboard.

The consistent use of the Scoreboard in these periodic publications highlights its value as a reliable and long-running data source. The added value, mostly come from its unchanged methodological approach that allows meaningful comparisons over time.

Given the large number of policy documents by the EU, we provide a closer look into who used the Scoreboard when and for which purposes. The EC is composed of 27 DGs plus the JRC (a DG in itself) as the in-house research facility. With 306 out of the 346 EU policy documents (see Table 2), the EC is the most important producer of policy documents citing the Scoreboard. Beyond the DGs of the EC, the European Investment Bank, the European Parliament and the European Economic and Social Committee each published 9 policy documents citing the Scoreboard, 4 by Eurostat, 2 by the European Central Bank and one by Eurofound.

One special case concerns the Commission SWDs and COMs discussed above, where we assign authorship to "EC".²⁷ Table 3 lists the EU institutions/DGs that published policy documents citing the Scoreboard at least twice; one column shows the total number of policy documents where a certain actor was involved, and the other the number of documents produced by the DG/Institution alone – the remaining publications where co-authored with non-EU actors. The names of the DGs were harmonised to the label in current use.

Actor	Documents	only EU	Actor	Documents	only EU
JRC	161	150	DG Research & Innovation (RTD)	52	38
EIB	10	8	Commission' Communications and Staff Working Documents (EUR COM)	27	27
EESC	9	9	DG Internal Market, Industry, Entrepreneurship and SMEs (GROW)	16	6
Eurostat	5	1	DG Communication Networks, Content and Technology (CONNECT)	9	1
ECB	2	2	DG Economic and Financial Affairs (ECFIN)	7	6
			European Parliamentary Research Service (EPRS)	6	6
			DG Climate Action (CLIMA)	2	0
			DG Competition (COMP)	2	1
			DG Education, Youth, Sport and Culture (EAC)	2	0
			DG Environment (ENV)	2	0
Total	187	170		125	85

Table 3. Policy do	cuments by EU Institutions
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Source: Overton, own elaboration.

Note: Eurofound, DG COMM, DG EMPL, DE ENER, DG External Policies, DG MOVE, DG REGIO, DG SANTE, DG TAXUD and DG TRADE used the Scoreboard in one policy document each. The total number of publications sums to 322 due to multiple counting when two or more EU institutions listed were involved in the same policy document (full counting method). The full names of acronyms of the Directorates-General (DG) of the European Commission, can be found here <u>Departments and executive agencies - European Commission (europa.eu)</u>.

²⁷ In section 4.3 we perform a citation content analysis of these documents as they are the most relevant ones for policy making in the EU context in our sample.

The most frequent users of the Scoreboard are those parts of the EU Commission that are responsible for its production, the JRC and DG RTD. DG RTD co-finances the Scoreboard since 2004, and therefore the Scoreboard specifically responds to policy questions and information needs especially of this DG. The next most important single user is the European Commission (EUR COM) in general, to which we assigned the authorship of Commission Staff Working Documents and Communications. Apart from DG GROW, all other DGs rather seldomly use the Scoreboard for their publications. Figure 6 below shows the number of policy documents by EU institutions over publication years of the policy documents, for the JRC, the DGs and other EU Institutions.



Figure 6. Number of EU institutions contributing to policy documents, by publication year

Source: Overton, own elaboration

Note: The number of EU institutions is calculated using the full-counting method

Overall, the JRC has been the EU institution that cited Scoreboard findings or used Scoreboard data most frequently (166 policy documents), closely followed by the policy DGs (126 policy documents), while the remaining institutions only occasionally referenced the Scoreboard, but – as we have seen in the case of the EIB – sometimes very thoroughly.

In terms of publication years, most EU policy documents citing the Scoreboard were published in 2013 and 2014 due to several serial publications that push the document count up. Most importantly, we observe the increase in the EU policy documents since 2021, reflecting renewed interest in industrial policy, an industrial policy that regards research and innovation as a core element for achieving goals such as competitiveness, productivity, strategic autonomy, economic security and resilience.

The policy documents of the EU were in 78.6% of the cases produced by one institution only, and the remaining documents were written by authors from 2 to 11 different institutions/organisations (74 policy documents in total). We produced a network graph (Figure 7) for these 74 documents showing the institutions of the authors of the policy documents (not those who published them). The green nodes represent EU policy DGs, grey nodes non-EU institutions such as research organisations, universities or think tanks, and the blue node represents the JRC. The grey nodes that

are unconnected to any DG/JRC are external studies on specific topics (such as programme evaluations) funded by the Commission. Overall, 137 different institutions, from which 121 are independent from the EU, contributed to the 74 documents underlying the network graph.²⁸ Note that a policy document can be classified as "EU' even if no EU-institution was involved in its production, as long as an EU institution published the document.



Figure 7. Network graph co-authorship of EU policy documents

Source: own elaboration, based on Overton. Note: Green indicates EU Commission DGs, blue the JRC and grey external institutions.

The largest number of cooperative outputs was produced by DG RTD (previously DG R&I) that cooperated in 14 publications with up to 10 different institutions, both from the EU Commission and external organisations. The second largest bubble is the JRC with 11 publications co-authored with again up to 10 institutions. DG GROW is the third EU institution with most co-authored policy documents citing the Scoreboard, with 10 publications with 2 to 10 different collaborating institutions.²⁹ The last significant bubble in Figure 7 is DG CNECT with 8 co-publications – in terms of cooperation intensity DG CNECT has the highest share of co-produced policy documents in all policy documents.

²⁸ For non-EU publications, only 54 were co-produced by more than one institution. Due to the low number we refrain from presenting a network graph here.

²⁹ The report with 11 different institutions is the "ERA industrial technology roadmap for low-carbon technologies in energy-intensive industries" published in 2022 and involves DG RTD, JRC, DG ENER, DG REGIO, DG GROW, DG CLIMA, DG EAC; DG ENV; EIC; EISMEA; Austrian Institute of Technology AIT

Regarding external institutions, we observe that Technopolis is involved in the largest number of publications, namely in 22 policy documents, of which 15 were produced with one to 6 partners. Fraunhofer ISI (Germany) is involved in 8 policy documents of which 7 are published with one to 5 partners, followed by Maastricht University (Netherlands) in 7 co-publications, 6 of them are the European Innovation Scoreboard 2018-2023.

We discovered only a few EU policy documents that were co-authored by more than one EU actor. Of all 306 policy documents with EU participation, in only 6 documents two or more actors from different EU institutions cooperated, with 2 to 8 different institutions involved. Overall, most EU policy documents are produced by only one institution/organisation, and if cooperation takes place then it tends to happen with the expertise from authors from external organisations (44 policy documents).

4.3 Areas and topics of influence

Building on the previous section about key actors, we now focus on identifying the predominant areas and topics of interest represented in scientific publications and policy documents. We begin by examining the scientific journals that have published articles citing the Scoreboard. Table 4 shows the number of publications from 16 journals that have 4 or more citations to the Scoreboard, which collectively account for 32% of our dataset (out of 206 journals).

Journal	Pubs	Citations	Top 10% Pubs	5 Year JIF
Sustainability	17	290	2	4
Research Policy	16	1192	7	10.4
Technological Forecasting and Social Change	9	209	3	12
Science and Public Policy	8	98	0	2.8
Economics of Innovation and New Technology	7	73	1	3.3
Eurasian Business Review	7	58	0	3.3
Journal of Cleaner Production	6	355	3	11
Industry and Innovation	6	82	0	4.5
Scientometrics	6	52	0	4.1
Management Decision	5	202	2	5.9
Journal of Technology Transfer	5	55	0	5.5
Industrial and Corporate Change	5	132	0	3.5
Technology Analysis & Strategic Management	5	29	0	3.5
Journal of Product Innovation Management	4	436	2	11.2
Energy Policy	4	69	0	8.5
R&D Management	4	139	0	6.5

Table 4	Top	scientific	iournals	with	more	citations	to th	he Sr	oreboar	ъ
	TOP	Scicituti	journais	vvitii	THULL	citations	10 11		JOI CDOUI	u

Source: own elaboration based on WoS

Notes: Pubs = Number of Publications citing the SB in a certain journal; Citations = Number of citations those publications have received until May 2024. Top 10% Pubs = Number of publications among the top10% cited publications within its WoS category and year; 5 Year JIF = Average number of times articles from the journal published in the past five years (2018-2022) have been cited in the Journal Impact Factor (JIF) year (2023)

The journals with more publications citing the Scoreboard are "Sustainability" and "Research Policy" (RP). RP is generally acknowledged to be the leading journal in the field of "innovation studies" (Fagerberg and Verspagen, 2009; Rossetto et al., 2018) and has a high 5-year journal impact factor when compared to journals in the same field. Notably, 7 out of those 16 publications in RP are among the top 10% more cited papers in their field and year (Belderbos et al., 2014; Filippetti and

Archibugi, 2011; Honoré et al., 2015; Kancs and Siliverstovs, 2016; Maçãs Nunes et al., 2012; Montmartin and Herrera, 2015; Szücs, 2020) and 4 out of those 7 publications use Scoreboard data. Among these 4 highly cited papers using Scoreboard data, Szücs (2020) investigates whether public research subsidies under the European Framework Programmes displace private R&D spending of large firms, finding no evidence of crowding out overall and identifying conditions under which subsidies actually boost private R&D; Filippetti and Archibugi (2011) investigate how the economic downturn affects innovation investments across Europe, identifying structural factors like human resources quality and high-tech sector specialization that mitigate its impact; Honoré et al. (2015) explores how corporate governance practices influence firms' R&D resources, revealing negative correlations between certain governance measures and R&D intensity; and Kancs and Siliverstovs (2016) examines the nonlinear relationship between R&D investment and firm productivity growth, highlighting sectoral differences in R&D investment and productivity gains.

Publications in "Sustainability" are a more recent trend, with all of them being published after 2015. They cover topics such as the determinants of green ICT adoption (Radu, 2016), responsible innovation (Gurzawska and Iakovleva, 2021), and the impact of R&D and innovation on sustainability (Borgida et al., 2022; Ravšelj and Aristovnik, 2018).

Within the 347 publications, 6 (1.7%) and 47 (13.5%) are among the top1% and top10% most highly cited papers in their respective research area and year. Since these ratios are above 1% and 10%, respectively, it indicates that publications are cited more frequently than the average publication in their area.³⁰ Interestingly, the 6 top1% highly cited publications, published in the last 5 years³¹, mostly cover topics unrelated to the economics of innovation, with only one using Scoreboard data directly. Schilde (2023) utilised the Scoreboard data to estimate the R&D investments of the top ten European defense firms in an article analysing the weaponizing of Europe. The other 5 top1% highly cited publications cite the Scoreboard for background information or specific insights and cover diverse topics. Alves et al. (2019) reviews the impact of pharmaceutical promotion on medicine use and advocated for better regulation. Weltmann et al. (2019) discusses the economic impact and significance of gas discharge plasmas in manufacturing. (Olvera-Vargas et al., 2021) investigates the synergistic effects of combining electro-Fenton and anodic oxidation with boron-doped diamond anodes for degrading organic pollutants in wastewater. (Oberthür et al., 2021) examine the role of global governance in the decarbonisation of energyintensive industries. Lastly, (Garibay et al., 2023) discuss the widespread adoption of artificial intelligence (AI) technologies and the associated unintended consequences, proposing 6 grand challenges for creating ethical and fair human-centred AI.

Figure 8 shows the distribution and dynamics of publications that cite the Scoreboard using WoS meso citation topics³² in three 6-year periods (2006-2011, 2012-2017 and 2018-23). The bulk of the papers are associated to "Management" and "Economics" (61% of all publications), with the relative importance of "Economics" increasing in time. Other topics with 10 publications or more are "*Engineering and Computer Science", "Sustainability Science", "*Clinical and Life Sciences", "Geography" and "Scientometrics".³³ This indicates that the SB insights and data were also relevant

³⁰ We also performed a citation count analysis of the policy documents. However, due to the large number of duplicates for EU documents, these figures are highly biased, since Overton links all documents from different sources and counts these links as citations. Cleaning the data for these duplicates was beyond the scope of the present paper.

³¹ The time citation window for articles published in 2023 is short and their classification as highly cited articles might change in the future. ³² See details here: https://incites.help.clarivate.com/Content/Research-Areas/citation-topics.htm

³³ The topics *Engineering and Computer Science" and "*Clinical and Life Sciences" are macro topics that include several meso topics.

for engineering, medical research (e.g. pharma R&D and innovation), green innovation, regional development and other research looking at indicators of science, technology and innovation.



Figure 8. Top 6 research areas influenced by the Scoreboard

Source: own elaboration based on WoS.

Note: Topics ordered by number of publications during the entire period. *Engineering and Computer Science" and "*Clinical and Life Sciences" are macro topics that include several meso-topics. There are a total of 326 meso-topics and 10 macro-topics.

The "**Others" category, which includes topics such as "Political Science" (5), "Agricultural Policy" (4), and "Operations Research and Management" (3), has also increased its representation over time. There are 39 meso-topics represented in this sample with at least one publication within a total of 326 meso-topics in WoS. This diversity underscores the broad applicability of the Scoreboard's insights and data.

Figure 9 shows a co-occurrence map of keywords frequently used in the literature citing the Scoreboard. Larger keywords indicate higher frequency, keywords that tend to co-occur in the same publications appear closer together, and colours represent the average year of publication in which a keyword is present.



Figure 9. Map of keywords appearing in scientific publications citing the Scoreboard.

The most frequent and central terms include expected concepts such as "innovation", "research & development", "technology", and "industry". The network map also reveals that terms like "China", "green innovation", and "eco-innovation" have a more recent average publication year (yellow), indicating a rising interest in Chinese innovation (Feng et al., 2023; He et al., 2018), or the effect of green innovation on firm performance (Aastvedt et al., 2021; Rezende et al., 2019). Older concepts include "foreign direct investment", "product development", "capabilities" or "multinational corporation".

We also performed a keyword analysis for policy documents. These documents are tagged with 3 keywords (topics) each (526 in total). Overton generates the keywords by analysing phrases and entities in the policy document and comparing them to relevant Wikipedia pages. The most popular tag in our set is "economy" used in over 40% of all policy documents, followed by "human activities" (38.6%) and "business" (21.4%). While most tags are broad,³⁴ Overton also provides more specific keywords for our analysis.

To compare frequently appearing keywords in scientific publications versus policy documents, we created an overlay map and ranked the keywords based on their frequency in each type of document. Figure 10 presents two density maps: the top map shows the most frequent keywords in scientific publications, and the bottom map shows the most frequent keywords in policy documents. Both maps use the same network structure as in Figure 9, but from different perspectives. The left map mirrors Figure 9 in terms of keyword intensity. In the right map, broader topics like "business",

Source: own elaboration based on WoS and VoSviewer Note: Min. number of occurrences=2; Normalization method=LinLog/modularity; Colors indicate average year of publication (Yellow = more recent; Purple = older)

³⁴ In particular the tag "human activities" does not allow to gain understanding on the topics of the respective policy document.

"economy", "European Union" and "economic growth" are more prominent but less central in the network, indicating that they are more marginal in scientific publications and co-occur less frequently with other keywords.



Figure 10. Density maps of keywords. Scientific publications (top) vs Policy documents (bottom)

Source: own elaboration based on WoS, Overton and VoSviewer

Note: Min. number of occurrences=2; Normalization method=LinLog/modularity; Colours indicate intensity of occurrences

We also analysed keywords unique to each set of documents and calculated the Log-Odds Ratio to compare the importance of terms between the two sets (see section 3.2.3 for details). In Table 5, we find that more technical keywords like "panel-data", "empirical evidence" and "model" and theoretical concepts like "knowledge spillovers", "absorptive capacity" and "open innovation" are often unique to scientific publications.

Conversely, policy-related concepts like "politics", "framework programmes for R&D" and "European Green Deal", along with specific topics like "venture capital", "greenhouse gas emissions", and "public-private partnership" are more specific to policy documents citing the Scoreboard. The appearance of policy related terms like "politics," "framework programmes for R&D," and "European Green Deal" is not surprising. However, the prominence of the keyword "venture capital" in policy documents but not in scientific publications is noteworthy. It appears in a broad spectrum of documents, including two ERA country reports³⁵, two editions of the Global Innovation Index by WIPO (2020 and 2023)³⁶, and one OECD report³⁷. It is also featured in an EU Commission document on boosting the biotech sector in the EU. Typically, "venture capital" is used in these policy documents as an indicator, or to discuss its role in firm financing and economic development. The absence of scientific publications with this keyword might indicate a potential research gap highly relevant for policy.

Table 5. Top10 divergent keywords in scientific publications and policy documents citing the Scoreboard

1

Scientific publicatio	n diver	gent k	keywords	Policy documents divergent keywords			
Konnorde	Ν	N N Log-Odds		N	N	Log-Odds	
Keywolus	Pubs	Pol	Ratio	Reywolds	Pol	Pubs	Ratio
firms	43	0	1.5	politics	17	0	1.4
panel-data	26	0	1.3	gross domestic product	16	0	1.3
knowledge spillovers	18	0	1.2	venture capital	10	0	1.2
mergers and acquisitions	16	0	1.1	framework programmes for R&D	10	0	1.2
model	16	0	1.1	european union	41	3	1.1
empirical-evidence	15	0	1.1	greenhouse gas emissions	8	0	1.1
firm performance	15	0	1.1	low-carbon economy	6	0	1.0
absorptive-capacity	27	1	1.0	public-private partnership	6	0	1.0
technological innovation	13	0	1.0	economic growth	30	4	0.9
open innovation	12	0	1.0	european green deal	5	0	0.9

Source: own elaboration based on WoS, Overton and VoSviewer

Note: We excluded from this table divergent keywords that had a high score but were very general and we couldn't infer any specific meaning from those terms. Examples for policy keywords are "Human activities", "Business", "Economy", "Nature"; for scientific keywords, some examples include "impact", "performance", "growth".

To gain deeper insights into the topics of policy documents, we compared keywords from EU versus non-EU policy documents. Here, we used the same Log-Odds Ratio to compare keywords specific to each group but frequently appearing in both. The top 5 keywords we see in Table 6 are those that appear more often and have a Log-Odds Ratio above 0.2.

³⁵ ERAWACTH country reports United Kingdom 2012 and 2013

³⁶ https://www.wipo.int/en/web/global-innovation-index

³⁷ OECD Reviews of Innovation Policy: Netherlands 2014

non-EU keywords	Ν	Log-Odds Ratio	EU keywords	Ν	Log-Odds Ratio
Innovation	38	0.28	Human activities	195	0.45
Research and development	20	0.24	Energy	16	0.56
Economic growth	20	0.35	Nature	9	0.63
Research	15	0.23	Sustainability	9	0.24
Politics	15	0.79	SMEs	8	0.29

Table 6. Top5 policy keywords prioritised in non-EU (left) vs EU (right) policy documents

Source: own elaboration based on Overton

Note 1: This analysis includes general policy terms that were excluded from Table 5 (same baseline)

Note 2: Some keywords, such as "low-carbon economy," "circular economy," and "climate change mitigation," have higher Log-Odds Ratios for EU keywords but are not shown in the table because they are not as frequent as the top five listed. Conversely, "China" and "Germany" have higher Log-Odds Ratios for non-EU keywords but are excluded for the same reason.

We find that non-EU documents have keywords more related to the content of the Scoreboard, whereas EU policy documents often feature more general keywords. This suggests that citations to the Scoreboard from non-EU policy documents are more specific to its content, while EU actors cite it in a broader range of contexts.

4.4 Citation content analysis

In addition to tracking trends and identifying actors and topics influenced by the Scoreboard, our focus extends to understanding the contextual usage of Scoreboard insights and data within citations. Given that data usage is more prominent in scientific publications than in policy documents, this quantitative analysis focuses exclusively on scientific publications. To complement this, Section 4.4 presents a qualitative analysis of how policy documents cite the Scoreboard.

Drawing from established literature on citation content analysis, we identified two primary types of citations — those utilising Scoreboard data and those incorporating Scoreboard insights — categorised into 7 distinct categories as outlined in Section 3.2: Insights (Background, Application, and Negative), Data (Single SB dataset, Multiple SB datasets, and SB dataset(s) combined with other datasets), and Null (Perfunctory citation).

Table 7 provides descriptive statistics, showing the distribution of publications across citation categories: insight (73%), data (53%), and null (<1%) citations. The most prevalent sub-category of citation is Insight-Application (54%), which encompasses references to specific findings, ideas, or facts from the Scoreboard reports. Examples include mentions of R&D intensity figures for specific sectors (Chamorro et al., 2012; Tavares et al., 2014; Wiesenthal et al., 2012); trends in R&D over time, including geographic patterns (Aastvedt et al., 2021; Laperche et al., 2011); the proportion of global R&D investment represented by top companies³⁸ (Castellani et al., 2017; Cincera and Veugelers, 2014; Coad, 2019; Gershman et al., 2016; Montresor and Vezzani, 2015); or the R&D investment of specific sectors or firms (Alves et al., 2019; Gulbrandsen and Stenqvist, 2013; Schuhmacher et al., 2013; Yin et al., 2020).

³⁸ One well known insight of the Scoreboard is that the 2500 companies covered account for around 80% of global corporate R&D investment. Within this set of companies, close to 40% of R&D is concentrated in the top 50 companies in the ranking (Nindl et al., 2023), suggesting that around one third of total global corporate R&D is controlled by a small set of firms.

Variable	Obs	Mean*	Std. Dev.	Min	Max
Citations	347	19.59	31.89	0	246
Pub Year	347	2017.64	4.10	2006	2023
Num authors	347	2.93	1.91	1	26
Insight	347	0.73	0.45	0	1
 Insight_Application 	347	0.54	0.50	0	1
 Insight_Background 	347	0.23	0.42	0	1
Data	347	0.53	0.50	0	1
- Data_1	347	0.36	0.48	0	1
- Data_multiple	347	0.17	0.38	0	1
- Data_combined	347	0.44	0.50	0	1
 Data_combined_patent 	347	0.22	0.41	0	1
Null	347	0.01	0.08	0	1

Table 7. Descriptive statistics

Note: The mean value for all variables except citations, pub year and number of authors, can be read as percentages.

A smaller proportion of publications (23%) cite the Scoreboard as Insight-Background, indicating that they reference it to contextualise or motivate their research without directly using Scoreboard data or acknowledging specific facts. Typically, these citations are integrated with other references within the text.

Among the 186 data citations, the majority (151) involve the combination of Scoreboard data with other datasets, while 35 publications rely solely on Scoreboard data for their research. Of these 151 publications, 84 combine the Scoreboard data with more than one other type of data (e.g., patents and publications), and 94 source their data form more than one other source (e.g., OECD and Eurostat). The average number of data types per paper is 2.0, while the average number of data sources (apart the Scoreboard itself) is 2.6. 75 publications use Scoreboard data in conjunction with multiple kinds of data from multiple sources, indicating a great level of complementary and potential for integration of Scoreboard data with other sources and types of data. Table 8 reports the main types of data (panel A) and the main data sources (panel B) that are combined with the Scoreboard.

Panel A		Panel B	
Type of data	N papers	Source of data	N papers
Patent	75	OECD	46
Company data	40	Patstat	39
Subsidiaries	21	Corporate annual reports	25
R&D	18	Eurostat	19
Publications	14	Academic literature	17
Macroeconomic variables	12	Orbis	15
Other kinds of data	88	Company websites	10
		Other kinds of sources	129

Table 8. Main type of data (panel A) and sources of data (panel B) combined with the Scoreboard

Source: own elaboration based on WoS

Note: only type of data and sources appearing in at least 10 papers are reported. Number of type of data and sources are fully counted.

There is significant variation in both, the quantity and nature of citations across different Scoreboard editions (see Fig. A.2 in the appendix). The 2018 edition received the most Insight citations (26), while the 2013 edition garnered the highest number of Data citations overall (23), and the most single Scoreboard dataset citations specifically (15). To assess whether specific citation categories change over time, we analysed the evolving number and shares of citation types across Scoreboard editions. The findings, depicted in Figure 12, indicate a relative decrease in data citations over time. This could be attributed in part to the potential decline in the novelty of Scoreboard data since the first releases in 2004-2006. However, Figure 12 requires careful interpretation as the lag in data citations is longer than for insight citations. To test this, we calculated the citation window between the publication year and the Scoreboard vintage cited, categorised by citation type (data vs. insight). We found that 75% of all scientific citations occur within five years of the Scoreboard's publication, with the share of insight citations being higher (82%) compared to data citations (69%).³⁹ These results indicate that data citations tend to have a longer citation window compared to insight citations. This is likely because integrating data into scholarly papers requires more effort, whereas insights can be cited more readily. Consequently, it is expected that the proportion of data citations for the latest Scoreboards in Figure 11 will increase in the future.





Source: own elaboration based on WoS.

Finally, we studied the possibility that publications citing Scoreboard data receive more citations than those citing only insights. The rationale is that the data created by the Scoreboard might be more valuable than the insights in the reports, leading researchers using the data to produce more novel and impactful papers. We analyse this using regression analysis (negative binomial and OLS), controlling for publication year and number of authors per paper.

In Table 9, the regression results reveal that the number of authors is positively associated with the number of citations, which aligns with the findings that collaboration typically enhances citation rates (Katz and Martin, 1997; Narin et al., 1991). We did not find any significant differences between data and insight citations or between publications that combine data versus papers not combining data. However, we found a positive and significant relationship between the number of citations and publications using patent data, especially those combining patent data with Scoreboard data. Publications that combine patent data with Scoreboard data receive, on average, 38% more citations than other publications, controlling for year.⁴⁰

Note: The citations they sum to more than 100% since a publication can be categorised both as insight and data citation.

³⁹ Figure A.3 in the appendix illustrates the number of publications citing the Scoreboard per time gap between the Scoreboard year and the publication year, by citation type. The share of data citations is only half for the shorter citation window (0-2 years), while it is almost three times higher for the longest citation window (more than 11 years).

⁴⁰ As a robustness check we run the same regression excluding publications from 2022 and 2023 due to the short citation window they have to be cited and potential noise it might generate in the overall results. The significance of patent data dummy continues to hold at 5% with a coefficient of 0.37 (37%).

Table 9. Regression results

	Dependent variable –							
Ind Variables		Citat	tion count pe	scientific publication				
	N	egative binon	nial		OLS			
	(1)	(2)	(3)	(4)	(5)	(6)		
Data (1-Ves)	0.053			-0.50				
Data (1-103)	(0.13)			(3.24)				
Num authors	0.19***	0.19***	0.18***	3.78***	3.81***	3.77***		
Nulli autiors	(0.031)	(0.030)	(0.029)	(0.84)	(0.84)	(0.83)		
SB Data Combined		0.20			2.30			
(1-Yes)		(0.13)			(3.24)			
Patent data			0.38***			8.82**		
(1-Yes)			(0.14)			(3.88)		
	0.12	0.12	0.098					
спарна	(0.075)	(0.075)	(0.076)					
Constant	1.97***	1.88***	2.03***	8.76**	7.41**	6.64**		
	(0.35)	(0.28)	(0.33)	(3.48)	(3.27)	(3.00)		
Year effects	Yes	Yes	Yes	Yes	Yes	Yes		
Observations	347	347	347	347	347	347		
R-squared				0.21	0.21	0.22		
Pseudo R-squared	0.066	0.067	0.068					

Source: own elaboration based on WoS

Note 1: Robust standard errors in parentheses; ***P<0.01, **P<0.05, *P<0.1.

There might be several reasons for this finding. First, combining Scoreboard data with patent data provides a more comprehensive view of innovation activities. The Scoreboard offers insights into corporate R&D investments, while patent data reveals information about the outcomes of these investments, and about which technologies firms do R&D. Second, studies that analyse both R&D investment and patent output can provide more reasonable findings about the effectiveness of R&D investments (Belderbos et al., 2010; Caputo et al., 2016; Leten et al., 2007), R&D spillovers (Aldieri et al., 2021, 2018), or the geographical distribution of R&D by top R&D investors (Alstadsæter et al. 2018, Belderbos et al. 2013). Third, combining patent with R&D microdata typically requires more sophisticated analytical techniques and methodologies. Publications that employ advanced methods might be seen as more rigorous and credible, leading to more citations.

4.5 Citations to the Scoreboard beyond science: in the EU Policy-making

In the previous section we analysed quantitatively the context in which the Scoreboard has been cited in science. In this section, we focus on assessing how policy documents cite the Scoreboard qualitatively. Specifically, we examine documents highly relevant for EU policy-making - *COMs* (European Commission Communications) and *SWDs* (Staff Working Documents). Before diving into the analysis of specific Scoreboard citations, we review shortly the EU Commission's framing of R&D before the Scoreboard was established.

4.5.1 Change in the narrative – structural R&D intensity gap

Policy makers have long regarded R&D expenditures as central for growth, productivity and competitiveness. R&D intensity targets have been one important objective of the EU's research and innovation policy agenda. In 2002, the EU Council in Barcelona set a target for the EU to spend 3% of GDP on R&D, with two-thirds coming from the private sector. The narrative that induced EU policy makers to set up such a target was the finding that EU firms were investing relatively less R&D than their counterparts in competing economies (intrinsic effect). This narrative was grounded on R&D intensity decomposition⁴¹ using BERD (country level) data, and not micro (firm level) data.

However, already the first edition of the Scoreboard in 2004 challenged this narrative. The decomposition analysis based on firm level R&D investment data revealed that the aggregate R&D intensity gap was due to differences in sector composition and the size of the sectors in the economies (structural effect). Contrary to the narrative at that time, the Scoreboard indicated that the main reason for the EU R&D intensity gap is that "...the mix of industrial sectors in the EU differs from that of the non-EU..." (p. 4) and specified that ".Much of the difference in the R&D/Sales ratios can be explained by the size difference in IT Hardware and Software & Computer Services between the EU and non-EU world. Because these two sectors together have a high R&D/Sales ratio relative to other sectors, their larger size in the non-EU rises the average R&D/Sales ratio for the whole group of non-EU companies. These structural differences raise important but complex issues that deserve attention in the future." (p. 6). With this important insight from very first edition about the reason of the R&D intensity gap, the Scoreboard had a direct impact on the EU policy-making narrative, as we will show in the following paragraphs.

The new message was taken up already in 2005, when Commissioner for Research, Janez Potočnik, in his press conference (Brussels, 10 December 2005) launching the 2005 edition of the Scoreboard stated that there was "*a lower concentration of EU-company R&D investment in sectors of high R&D intensity…leading to an increasing gap in aggregate R&D investment compared to their competitors*". In November 2006, the Bureau of Economic Policy Advisers (BEPA) forwarded a note to the EC President Barroso pointing out these Scoreboard results. In 2007, the report "The EU's R&D Deficit and Innovation Policy" based on contributions of Commissioner Potočnik's High Level Expert Group on 'Knowledge for Growth' (rapporteur Mary O'Sullivan⁴²) suggested that *"the EU private R&D investment deficit is mainly due to a sectoral composition effect*".

In the years that followed, the EC further endorsed this new narrative. This is, e.g., the case of the European Competitiveness Report 2011, part of the *COM* "Industrial Policy: reinforcing competitiveness"⁴³ (p.50) that stated: "...*This means that the traditional support to R&D may help cover the gap between private and social returns to R&D may not help close the gap across [world] regions. Indeed, [world] regions with lower intensity are not necessarily regions where individual firms invest less in R&D because similar firms (in terms of size, sector, turnover, etc.) tend to be similar as well as regards R&D intensity...".*

At the beginning of the 21st century, industrial policy was not very popular in the EU, and policy interventions were limited to a few industries, such as R&D subsidies to coal, nuclear energy, and

⁴¹ The decomposition of the aggregate corporate R&D intensity is able to explain the differences in R&D intensity between countries by determining whether is the result of firms' underinvestment in R&D (intrinsic effect) or of the differences across sectors (structural effect).

⁴² https://ec.europa.eu/invest-in-research/pdf/download_en/rdd_deficit_report0207.pdf

⁴³ European Competitiveness Report 2011 Commission staff working document SEC(2011) 1188 accompanying document to the Communication — Industrial Policy: reinforcing competitiveness (COM(2011) 642 final) (SEC(2011) 1187 final)

aerospace⁴⁴. However, since 2005, EU policy makers started to consider the new narrative on the corporate R&D gap as framed in the Scoreboard. Lately, it was fully endorsed it the *New Industrial Policy* ⁴⁵ for the EU. It considers corporate R&D investment as central to many recent EU policy initiatives, such as Industrial alliances (solar, batteries, hydrogen, etc.), IPCEIs (chips, batteries, hydrogen, etc.), Net Zero Industry Act, Critical Raw Materials Act, Pharmaceutical Strategy, Space & Defence, EU Chips Act, Bio-manufacturing, Advanced Materials, RePowerEU, Strategic Technologies for Europe Platform. Moreover, the relevance of the structural composition of an economy has percolated until the regional dimension of R&D with the launch of *Smart Specialization* and later the *Partnership for Regional Innovation* approach by DG REGIO (Foray 2018; Pontikakis et al, 2022). In spring 2024, Mario Draghi, anticipating his report on EU competitiveness, stated that "....We are lacking a strategy for how to keep pace in an increasing cutthroat race for leadership in new technologies. Today we invest less in digital and advanced technologies than the US and China, including for defence, and we only have four global European tech players among the top 50 worldwide...".⁴⁶

4.5.2 New policies in main EU policy documents using Scoreboard results

As described in section 3.2.2., the results of the Scoreboard have been cited in important EU policy documents, *European Commission Communications (COMs)* and *European Commission Staff Working Documents*. Both types of documents constitute an important (new) knowledge background and could have had an impact on the EU policy-making process. Such new knowledge when are reported/cited in the *COMs/SWDs* enshrines the highest relevance as a reference. The Commission is the only EU institution that can submit proposals – in the form of COMs with their related SWDs - for new legislation for adoption by the EU Parliament and the EU Council. The analysis of *COMs* and *SWDs* captured by this study highlights that the Scoreboard results supported several policy messages. Out of 27 of these documents (see Table 3 on policy documents by EU institutions), we report the most distinguished messages selected from 17 (2 COMs and 15 SWDs) of them^{47,} that can be summarized as follows:

1. Structural change: The EU corporate R&D intensity gap is mainly due to the structure of its economy compared to main competing economies. Global corporate R&D is highly concentrated in 4 major sectors: ICT producers, health, ICT services and automotive. The first 3 are sectors with high R&D intensity, while automotive has only medium R&D intensity. US companies lead in R&D investment in the first three sectors, while the EU companies lead in automotive R&D (and health being the EU's second largest sector in terms of R&D investment). Corporate R&D efforts can lead to the creation of entirely new products or technologies, this in turn can result in a positive impact on competitiveness. Therefore, a structural change towards more and larger companies in high-tech/R&D intensive sectors in the EU is necessary, claiming for urgent action as Asian economies and the US are moving forward quickly and expose Europe's weaknesses more than before.⁴⁸

⁴⁴ OECD – Nuclear Energy Agency (2004) Government and Nuclear Energy. NEA No. 5270. OECD Publications, Paris; Pelkmans, J. (2006). European Industrial Policy. Bruges European Economic Policy (BEEP) Briefing 15/2006

⁴⁵ European Commission (2021) Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery. COM(2021) 350 final. Brussels.

⁴⁶ Mario Draghi's speech at the high-level conference on the European Pillar of Social Rights - Brussels, April 16, 2024

⁴⁷ For example, we did not report the messages from European Commission SWD(2021) 103 final as this document cites the Scoreboard because its firms constitute the sample of "The 2020 EU Survey on Industrial R&D Investment Trends".

⁴⁸ Relevant documents: European Commission, COM(2013) 149 final; European Commission SWD(2014) 23 final; European Commission, SWD(2017) 221 final; European Commission, SWD(2020) 508 final European Commission SWD(2021) 37 final - PART 3/19; European Commission, SWD(2021) 352 final; European Commission SWD(2022) 187 final; European Commission, SWD(2023) 167 final.

2. Green Deal: Top R&D investors appear as major players in the development of green technologies. Various editions of the Scoreboard analysed the companies' inventions and new technologies in green transportation, including aerospace and defence. EU companies lead in high-value patents and also in inventions relevant to circular economy. Environmental regulations play an important driving role also for top R&D investors, thus it is crucial that the EU maintains its strong position on its Green Deal objectives. However, specific efforts will be needed to pursue the requirements of the Green Deal in order to sustain leadership and remain competitive on global markets. The EU is in a unique position to act as a global standard setter in intellectual property, due also to its leading position in green technologies. Policy which encourages the participation of companies, including SMEs in R&D and/or specialisation agreements, could have a positive impact on the environment.⁴⁹

3. Young firms, SMEs, technology transfer, industry clusters: Compared to the US and China, the top R&D investing EU companies are fewer, older, and smaller. To reduce the technology gap vis-a-vis its major competitors, the EU should support the creation of new companies (startups) and facilitate SMEs and younger firms to grow and become large world innovators and market leaders. This can be achieved by focusing on investments that expand the innovation base and by facilitating knowledge spillovers between large companies and startups and SMEs. Moreover, the R&D investments of the EU companies do not sufficiently translate into productivity gains. The EU makes too little use its world-leading research in industry and must ensure a better transfer of that R&D into the economy. Incentivising investment in intangible assets could boost the innovation capacity of small and young firms. Industry clusters are important in high R&D-intensity sectors such as integrated circuits, given the need to specialise ⁵⁰

4. Crises and resilience: Corporate R&D investments help the EU economy to be resilient and as key for economic recovery.⁵¹

The citation of the Scoreboard in the most prominent policy documents of the European Commission underscores its critical role in shaping EU policy and legislative proposals. By being enshrined in Commission Communications and related Staff Working Documents, the Scoreboard's findings not only validate its significance but also influence and drive strategic policy decisions at the highest levels of the EU.

⁴⁹ Relevant documents: European Commission, COM(2020) 760 final; European Commission, SWD(2020) 214 final; European Commission SWD(2021) 37 final- PART 15/19; European Commission SWD(2021) 307 final; European Commission, SWD(2021) 352 final; European Commission SWD(2022) 40 final - PART 1/2; European Commission SWD(2022) 187 final; European Commission, SWD(2023) 167 final; European Commission SWD(2023) 219 final.

⁵⁰ Relevant documents: European Commission SWD(2018) 307 final; European Commission, SWD(2020) 214 final; European Commission SWD(2021) 154 final; European Commission, SWD(2021) 352 final; European Commission SWD(2023) 118 final; European Commission, SWD(2023) 167 final.

⁵¹ Relevant documents: European Commission SWD(2022) 40 final - PART 1/2; European Commission SWD(2022) 187 final.

5 Discussion and Conclusions

The EU Industrial R&D Investment Scoreboard was created by the European Commission - Joint Research Centre (JRC) together with Directorate-General for Research and Innovation (DG RTD) to monitor the R&D activities of innovation leaders and provide policy recommendations for the EU. Since its first edition in 2004, it has become a crucial tool for researchers and policymakers, offering unique data on corporate R&D investments and relevant policy insights. This paper examines citation trends in both scientific publications and policy documents to understand the usage and impact of the Scoreboard's data and insights, the reach in terms of actors and topics, and the dynamic changes in citation patterns.

Our analysis reveals that the Scoreboard is cited more frequently in policy documents than in scientific publications. However, the share of citations from scientific publications has been increasing over time, indicating growing academic interest. One important finding is the differing citation window length for policy and scientific publications, with policy documents citing the Scoreboard significantly more quickly. This rapid citation by policy documents can be attributed to the immediate relevance and utility of the Scoreboard's timely monitoring insights for policy discussions, which was one of the primary motivations for creating the Scoreboard, as R&D data from statistical offices takes much longer to become available.

The most frequent users of the Scoreboard are the JRC and other European Commission services, particularly DG RTD and DG GROW. While EU policy institutions and intergovernmental organisations remain the main actors citing the Scoreboard in policy documents, there has been a rise in citations by think tanks, reflecting a diversification in the Scoreboard's policy impact. Among scientific institutions, core users often have strong connections to the JRC, but numerous research groups without such ties also cite the Scoreboard, highlighting its broader scientific influence. Notably, there is minimal engagement from US, Japanese, and Chinese institutions, suggesting limited awareness or interest in the Scoreboard's data and insights.

The Scoreboard is frequently cited in high-impact journals, and these citing papers tend to have a higher citation impact than average, underscoring the Scoreboard's significance in academic research. The core topics of these publications are related to management and economics of innovation, but there is a diverse range of subjects, including health, governance, energy, and artificial intelligence, especially among the most impactful publications citing the Scoreboard.

For citations by scientific publications, we performed a citation content analysis. We found that insight citations are more frequent than data citations and those data citations have a longer citation window, meaning that it takes more time for research to use a Scoreboard dataset, than to cite a specific insight from the report. Insight-application citations, such as the proportion of global R&D investment represented by top R&D investors, R&D intensity figures per sector, trends in R&D over time, and the R&D investment of specific sectors or firms, are the most common, illustrating the utility of the Scoreboard's analyses. Interestingly, the share of data citations has been decreasing, possibly due to the declining novelty of Scoreboard data since its first releases. We also tested if publications citing Scoreboard data had more citation impact than those citing insights alone and found no significant difference, indicating that both data and insights are equally relevant for the scientific community. However, we find that publications combining patent data with Scoreboard. We argue that this happens because these publications use complementary data that allow to understand topics difficult to estimate empirically like the effectiveness of R&D investments or R&D spillovers measurement.

We also analysed the impact of the Scoreboard in policy documents and found that, since its early years of publication, the Scoreboard has become a key reference in the EU policy-making process. Its analytical findings have significantly influenced the narrative around the EU's corporate R&D gap compared to its main competitors. As a result, it has highlighted the need for structural changes within the EU towards high R&D intensity sectors, rather than simply increasing business R&D investment across all sectors. Additionally, the Scoreboard has provided solid evidence of the EU's leadership in green innovation, underscoring the need for specific efforts to meet the requirements of the European Green Deal and to maintain competitiveness in global markets. Policymakers have also relied on the Scoreboard's analyses to emphasize the importance of young innovative SMEs and their role in the innovation, growth and knowledge transfer process. Overall, the Scoreboard has demonstrated to policymakers that industrial R&D investment is crucial for the sustainable competitiveness, productivity, resilience, and crises recovery of the EU economy.

In conclusion, the EU Industrial R&D Investment Scoreboard has influenced both policymaking and scientific research. Its relative growing impact in science, diverse user base in terms of topics and actors, and relevance in policy debates about industrial policy and structural change demonstrate its vital role in the science-policy interface.

This study has limitations related to the databases used, which cover only a share of the total scientific and policy impact. However, our use of Overton for policy impact analysis is an important contribution of this paper, which can be replicated and expanded to other policy documents, to compare how they facilitate the flow of knowledge between scientific research and policymaking. Another limitation in the citation content analysis is that it is human-based and prone to interpretation. We addressed this by having more than one author categorize each paper, ensuring a more robust and reliable analysis.

Future research could explore how corporations (private sector) and business associations use Scoreboard insights and data, potentially through interviews, as we could not find a systematic way to collect this type of information. Another complementary comparison would be to analyse the characteristics of the bodies downloading the Scoreboard from the website. Additionally, future studies could expand our quantitative citation content analysis to include scientific publications in other languages, other types of scientific documents (e.g., conference proceedings, book chapters), and policy documents. Finally, although we found that Overton data has a lot of potential, there are areas for improvement in terms of scope, cleaning duplicates, classifying sources, and refining keywords.

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7 Annexes

Table A.1. Citation matrix between Scoreboard edition and publication and policy document year



		POLICY DOC YEAR																		
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
SCOREBOARD EDITION	2004		1																	1
	2005	3	1																	4
	2006		4	10	2	2	1	1	1											21
	2007			4	14	5	4	1		1										29
	2008			1	9	3	3	2	1	1										20
	2009				4	14	6		4	1								1		30
	2010					1	17	13	11	1		1				1				45
	2011							7	20	9	2	2		1						41
	2012								20	15	6	1	1			1				44
	2013								2	20	18	8	2	2						52
	2014										15	18	7	1	1			1		43
	2015											11	8	6		2	1			28
	2016												23	18	5					46
	2017													23	12	8		1		44
	2018													1	21	18	5			45
	2019															24	19	8	1	52
	2020															1	25	8	9	43
	2021																	30	11	41
	2022																	3	26	29
	TOTAL	3	6	15	29	25	31	24	59	48	41	41	41	52	39	55	50	52	47	658



Figure A.1. Cumulative Scoreboard citations in policy documents, per vintage and year, 2005-2023

Source: Authors calculations, based on Overton data

Note: Scoreboard citation year on the horizontal axis. The first Scoreboard vintage cited in a policy document was Scoreboard 2006 in the year 2005, while Scoreboard 2004 was cited only once in 2007.



Figure A.2. Trends in citation type per Scoreboard vintage



Figure A.3. Citation window between report and citation in scientific publication, per citation type

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