Heliyon 11 (2025) e41335

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

# Italy's excellence in research

Rosaria Ciriminna [a,*], Cristina Della Pina [b,**], Mario Pagliaro [a,***]

[a] Istituto per lo Studio dei Materiali Nanostrutturati, CNR, via U. La Malfa 153, 90146 Palermo, Italy
[b] Dipartimento di Chimica, Università degli Studi di Milano, via Golgi 19, 20133 Milano, Italy

ARTICLE INFO

*Keywords:*
Excellence in research
Research excellence in Italy
Scholar rankings
Highly ranked scholars
Research policy

ABSTRACT

We analyze excellence in research carried out in Italy using the Highly Ranked Scholars (HRS) ranking of the top 0.05 % of all >30 million scholars. Published by research database ScholarGPS, the ranking is based on classification of over 140 million scholarly publications (weighting each publication and citation by the number of authors, and excluding self-citations). We investigate the outcomes of both prior five-year (2018–2022) and lifetime rankings. Results are informative in many aspects, including in comparison to other nations. The critical analysis of the results may inform policy efforts aimed at opening up a positive long-term economic development perspective for Italy. The analysis may also inform research policy efforts in other countries aimed at connecting research with economic and societal development.

## 1. Introduction

Italy belongs to the world's top ten countries in terms of yearly output of scientific publications in science and engineering (S&E). For example, with 90,586 S&E articles (publications in peer reviewed journals and from conference proceedings) in journals and proceedings indexed by research database Scopus, Italy in 2022 ranked 7th in the world (after Japan, and prior to Russia) [1].

The world's top scholars (active, retired, and deceased) in terms of productivity (number of publications), quality (number of citations), and impact of the most cited publications (h-index) were recently identified by a novel research database (ScholarGPS).

Using an artificial intelligence (AI) algorithm, this new research database identified the Highly Ranked Scholars (HRS) in the top 0.05 % of all >30 million scholars (active, retired, and deceased) based on classification of over 140 million scholarly publications, weighting each publication and citation by the number of authors, and excluding self-citations [2].

Regardless of the relatively large number of publications (and citations), Italy's scientific system suffers from poor meritocracy with recruitment, tenure and promotion being not linked to scientific merit [3–5]. For example, promotion to the rank of full professor in Italian universities does *not* correlate with scientific merit, but rather with the number of years that the candidate has belonged to the same university as the president of the selection committee, and to previous research collaboration with the committee's president [3]. Another example are candidates eventually hired as associate or full professors at the University of Florence between 2014 and 2021. The non-recruited candidates had on average significantly higher *h*-index by the year of qualification, the year of the public call, and at the end of the investigated period, and also better scientific productivity after the selection was held [4].

Learning in which fields a country excels in scholarly research is useful to better understand how to effectively allocate funds to

* Corresponding author.
** Corresponding author.
*** Corresponding author.
*E-mail addresses:* rosaria.ciriminna@cnr.it (R. Ciriminna), cristina.dellapina@unimi.it (C. Della Pina), mario.pagliaro@cnr.it (M. Pagliaro).

https://doi.org/10.1016/j.heliyon.2024.e41335
Received 25 July 2024; Received in revised form 10 December 2024; Accepted 17 December 2024
Available online 18 December 2024

support "the next level of highly excellent people" [6]. Today's emphasis on academic research excellence, though, carries with itself a risk for which, as in the Matthew effect in science [7], public research funds are focused by governments on the excellent research centres and excellent scholars, diminishing funding for those centres not ranked in excellence rankings [8]. Seen from a complementary perspective, there is a large societal potential for "excellent" scientists that remains largely untapped [5].

In this study, we critically analyze the outcomes of Italy's HRS ranking, five-year (2018–2022), comparing it also with the outcomes of HRS, lifetime, in terms of field, discipline, and affiliation. The outcomes of the critical analysis may inform future efforts of Italy's policy makers and researchers aimed at opening up a long awaited positive long-term development perspective for Italy. Indeed, we agree with economist Heimberger: there has been "too little critical reflection on how EU policy-makers could help Italian policy-makers to develop a credible approach to opening up a positive long-term economic development perspective for Italy, beyond sticking to the national pandemic recovery plan in the context of Next Generation EU" [9]. Italy, for example, is deindustrializing since over two decades [10], while young graduates and doctoral graduates leave the country at unprecedented rate (30 % of 1.3 million young workers aged between 20 and 39 years who left the country between 2012 and 2021, were university graduates [11]).

## 2. Methods and materials

The ranking process has been lately described in detail elsewhere [12]. In brief, the ScholarGPS Rank is the geometric mean of the productivity (archival publication count), impact (citation count), and fractional *h*-index as a proxy for quality. The analysis takes into account archival scholarly literature consisting of over 140 million publications (peer-reviewed journal articles, book chapters, conference papers, books, and patents). Publications associated with a memoriam, commentary, celebration, book review, discussion, correction, rebuttal, are not included. Similarly, preprints are excluded. In brief, all scholars (a sample of more than 30 million scholars) include inactive, deceased, and retired scholars. An active scholar is one who has published an archival publication within the preceding five years period of the current year.

Compared to existing rankings of scholars such as Clarivate's Highly Cited Researcher relying on citation counts [13], Scopus ranking for the top 2 % of scientists based on both citation counts and the *h*-index [14], or Google Scholar ranking based on the overall *h*-index, the ScholarGPS ranking method is relevant to specific fields, disciplines, and specialties. This avoids reliance on journal-based classification techniques to associate publications with particular fields and disciplines, as it happens with both WoS and Scopus (both assign scholars into broad fields or disciplines, but do not assign them to more granular specialties), which may lead to classification errors when ranking a scholar that may be assigned to multiple fields and disciplines [15]. ScholarGPS service considers scholarly work in all fields using the same 14 broad fields used by Milojevic [15] aggregating data in 177 disciplines from these field and in over 350, 000 specialties. Furthermore, the method relies on its own database used to assess every scholar identified by AI-based data mining technology to identify the three indicators mentioned above: number of publications; number of citations; and *h*-index, in granular (hundreds of thousands) research categories based on lifetime as well as for work published in the last 5 years.

In detail, the ScholarGPS database considers scholars in each of 14 fields; in each of 177 disciplines that comprise the fields (each discipline is a subset of only one field); and in each of over 350,000 specialties. The 14 fields are: agriculture and natural resources, allied health, arts and humanities, business and management, dentistry, education, engineering and computer science, law, life sciences, medicine, pharmacy, physical sciences and mathematics, public health, and social sciences.

Concerning data quality, preprocessing algorithms improve it by eliminating nonarchival publications and managing publisher errors, including metadata formatting mistakes of raw publication metadata sourced from various sources, including (but not limited to) Crossref, PubMed, and Unpaywall. Citation counts taken into account exclude self-citations [16], weighting each publication and citation by the number of authors [17]. If, for instance, a publication has two authors, each is credited with 0.5 publications and half of the citations to the publication. Publications with more than 30 authors are not included because it is not possible to distribute credit among the authors. The *h*-index has been heavily criticized in the literature [18]. The methodology used by ScholarGPS employs the scholar's fractional *h*-index [18], namely a fractional analogue of the *h*-index calculated by fractional allocation of citations among authors. Combined with the elimination of self-citations, this fractional allocation neutralizes the inflationary effects of hyper-authorship on impact indicators, though continuing to reward collaborative production of impactful scientific research [18].

Scholar rankings are conducted in four categories: overall (all fields), by field, by discipline, and by specialty. Highly Ranked Scholars are those with personalized ScholarGPS Top Percentage Rank (pSTPR, overall, field, discipline or specialty) of 0.05 % or better. A HRS may be given the award for her/his overall performance, and/or for performance in her/his field, discipline and specialty. Some scholars are recognized as HRS in multiple categories. Scholars may be placed into one of these categories based on their lifetime achievements, or based on their ranking as determined over the last five years. This is important because, as put it by public management scholar Borins, contrary to many other rankings including Google Scholar "that provides no information about the individual's peer group and how they compare to that group", ScholarGPS provides any scholar's complete publication record and allows to check "how they compare to other scholars in the field(s), discipline(s), or specialties in which they do research" [19].

## 3. Results and discussion

### 3.1. Italy's HRS, last five years

The set of HRS for Italy in the last five years (2018–2022) evaluation period includes 146 scholars (Table S1), and not 151 as reported by the website by June 2024 and subsequently reduced to 148 (see below) [2]. The algorithm used to produce the ranking erroneously included in the ranking 5 scholars (Ruben Martin, Paolo Melchiorre, Arjan W. Kleij, Núria López and Ville Vaskonen) who

actually work in Spain (at Barcelona Institute of Science and Technology). We further polished the data set by checking the correspondence between each institution and the affiliated HRS. In one case (European University Institute) the HRS identified is actually working at the University of Turin, where it opens the list of 6 HRS. Two scholars (Mario Coccia and Mario Pagliaro) actually employed at Italy's Research Council (CNR) were affiliated by the algorithm to Collegio Carlo Alberto (where Professor Coccia teaches) and to Istituto per lo Studio dei Materiali Nanostrutturati (the CNR institute where Dr Pagliaro works). Nicola Maffulli, affiliate to the University of Salerno, was affiliated by the database to Keele University.

Table S2 ranks the institutions employing Italy's HRS by the number of HRS for the past five years. Affiliated with 50 different institutions, the scholars work across the whole country, including Sicily, the most southern region. Yet, the number of HRS is heavily concentrated in the North, specifically in Milan that has 4 institutions in the top 10: the University of Milan opening the rank, the Università Cattolica del Sacro Cuore, Polytechnic University of Milan and University of Milano-Bicocca. The only exception is the University of Naples and its sister university located in Salerno, a relatively young university established in 1969, distant less than 50 km from Naples. Investigation of Table 1 clearly shows that only two institutions in the top 10 are based in southern Italy, namely the Universities of Naples Federico II and of Salerno. Sicily, Italy's largest and most southern region, has seven scholars in the ranking (3 at the University of Messina, 2 at Catania's and 1 at Palermo's Universities), and one based at Italy's Research Council. For comparison, Italy's most northern region (Trentino Alto Adige) has 5 HRS, three in Trento and two in Bozen (Bolzano). Thirteen HRS are hosted in two universities (Padua and Verona) in Veneto distant just 80 km from each other.

The analysis of the field and discipline in which Italy's Highly Ranked Scholars in prior five years highlights the current key research areas in which Italy's research excels. Table 1 shows that medicine, engineering and computer science, and physical sciences and mathematics are the three main fields in which Italian scholars excel.

Life sciences is also an important field in which Italian researchers perform well (16 scholars), especially when the outcome is combined with the 6 HRS in Pharmacy and pharmaceutical sciences and 1 in Public health. Similarly, the 9 Italian top scholars in the Social sciences, chiefly specializing in economics, complement the 4 in Business and management. Finally, Italy has 2 HRS in Arts and humanities, both specializing in architecture. Remarkably, in the five-year (2018–2022) evaluation period Italy has no HRS in the fields Education, Allied health, Law, Agricultural and natural resources, and Dentistry.

The analysis of the field and discipline in which Italy's Highly Ranked Scholars in prior five years shows the current key research areas in which Italy's research in medicine excels. In general, Italy is represented in 18 out of the 30 disciplines comprising medicine. In further detail, in medicine Italy's scholars excel in internal medicine, cardiology, surgery, and neurology. In Engineering and Computer Science, Italy is represented by top scholars in 9 out of the 15 disciplines comprising the field. In particular, Italy's engineering scholars excel in Civil and Environmental Engineering (8 HRS), Electrical and Computer Engineering (7 HRS), and Computer science (5 HRS). In Physical Sciences and Mathematics Italy's has top scholars in 6 out of the 8 disciplines comprising the field. In particular, Italy has 8 HRS in Chemistry, 7 in Physics and 4 in Mathematics. Only the disciplines Oceanography and Atmospheric sciences do not include Italy-based HRS in the field Physical Sciences and Mathematics.

### 3.2. *Italy's HRS, lifetime*

The set of Italy' HRS, lifetime, includes 148 scholars (Table S3), and not 170 as returned by the website by June 2024 [20] and subsequently reduced to 164 (see below). The AI algorithm identified one scholar (Greg L. Plosker) as affiliated to the University of Catania, and another (Marc Jeannerod) as affiliated to the University of Cassino and Southern Lazio. This is not the case as Plosker is a medicine scholar based in New Zealand and Jeannerod was affiliated to France's University of Lyon. The algorithm also identified K. L. Ngai as a scholar of the University of Pisa, whereas he was affiliated to the Naval Research Laboratory in the USA. Colin Sheppard was affiliated to the University of Oxford and subsequently to National University of Singapore, and not to Istituto Italiano di Tecnologia. Ivo Brosens was affiliated to Catholic Leuven University, and not to Sapienza Rome University. Michele Parrinello is a physicist who carried out most of his career at the University of Trieste, then at SISSA, IBM Zurich Research Lab and eventually at ETH Zurich, and not at Istituto Italiano di Tecnologia, joined after retirement. Brian A. Hemmings and Matti Aapro carried out their work in Switzerland and not, respectively, at the University of Florence and at European School of Oncology. Peter Reichard was an eminent biochemist in Sweden, and not at the University of Padua, visited after his retirement. Similarly, Adayapalam Natarajan cytogeneticist was a professor at Leiden University and not an affiliate to Tuscia University, visited after retirement. Medicine scholar Dennis Revicki carried out his research in the USA, and not at University of Rome Tor Vergata. Aron Goldhirsch was a medicine scholar who carried out most

**Table 1**
Number of Italy' HRS, lifetime, and last 5-years (for the evaluation period 2018–2022), by research field.

| Field | Number of HRS, lifetime | Number of HRS, last five years |
|---|---|---|
| Medicine | 48 | 55 |
| Engineering and Computer Science | 13 | 29 |
| Physical Sciences and Mathematics | 41 | 23 |
| Life Sciences | 32 | 16 |
| Social Sciences | 6 | 9 |
| Pharmacy and Pharmaceutical Sciences | 6 | 6 |
| Business and Management | 0 | 5 |
| Arts and Humanities | 0 | 2 |
| Public Health | 3 | 1 |

of his research in Switzerland, and not at Milan's Istituto Europeo di Oncologia. Leopold Flohé is a German biochemist who spent his career in Germany, and not at the University of Padua, visited after retirement. Paul Frampton is a physicist who carried out research in Great Britain and in the USA, and not an affiliate of the University of Salento. Political scientist Hanspeter Kriesi carred out scholarly work in Switzerland, and not in Italy. Biochemist Narendra Tuteja works in India and is not an affiliate of the International Centre for Genetic Engineering and Biotechnology in Italy, but rather in New Delhi. Peter Sleight was a cardiologist who worked in Great Britain, and not an affiliate of University of Milano-Bicocca. Three chemistry scholars (Antonio M. Echavarren, Kilian Muñiz, and Vladimir V. Grushin) were erroneously affiliated by the AI algorithm to Barcelona Institute of Science and Technology, Italy. This is not the case, because the aforementioned Institute is based in Spain. Giacomo Rizzolatti is not affiliated with the Italian Research Council but with the University of Parma. Nicola Maffulli is affiliated to the University of Salerno, and not to Keele University. Ernesto Carafoli was affiliated to the University of Padua for the last 14 years of his career (1990–2004), after 25 years at ETH Zurich, and not to the Venetian Institute of Molecular Medicine. Bruno Scrosati was affiliated to the University of Rome La Sapienza, and not to Istituto Italiano di Tecnologia. Rita Levi-Montalcini was affiliated to Consiglio Nazionale delle Ricerche, and not to the European Brain Research Institute, a foundation she established after her retirement. Sergio Trasatti was an eminent electrochemist, and not a scholar in the Life Sciences, as returned by the AI algorithm. His correct field was Physical Sciences and Mathematics and correct discipline was Chemistry.

### 3.3. Trends in Italy's excellent and regular research

Comparison between the number of HRS, lifetime, and HRS, last five years, reveals substantial changes for excellence in research in Italy. Table 1 indeed shows evidence that in Italy significant HRS redistribution has occurred across the various fields. Research in medicine, a field in which Italy's scholars excelled in the past, further improved with the number of HRS having gone from 48, lifetime, to 55 today. Even more significant was the improvement of research of Italy's scholars in Engineering and Computer science, in which the number of HRS more than doubled from 13, lifetime, to 29, last five years.

On the other hand, the number of top scholars in the Life Sciences in Italy halved from 32 HRS, lifetime, to 16, last five years. A similar >43 % decrease in the number of HRS was observed for the field Physical Sciences and Mathematics in which the number of HRS went from 41, lifetime, to 16, last five years. No variation instead was observed for the low (6) number of the Italy's HRS in Pharmacy and Pharmaceutical Sciences. Finally, a substantial increase in the number of Italy's top researchers was observed in Social Sciences and even more in Arts and Humanities and Business and Management. In the latter cases, Italy respectively went from no HRS, lifetime, to 5 HRS, and from no HRS, last five years, to 2 HRS.

This shows evidence of a lack of Matthew effect in research carried out in Italy. The outcome is not surprising because when the government tried to foster a Matthew effect introducing a new mechanism allocating more public funds to the best-performing universities [21], Italian universities reacted to the research assessments (three so far, VQR 2004–2010, VQR 2011–2014, VQR 2015–2019) through promotions and new recruitments in the research fields in which they consistently ranked *below* the national average [22]. In other words, Italy's universities opted to strengthen the weak sectors.

Following the introduction in 2011 of a national habilitation scheme in academic hiring and promotion based on bibliometric indicators (*i.e.*, number of publications, total number of citations, and *h*-index), Italian scholars quickly increased the number of annual publications. For example, comparison of number of papers published between 2013 and 2016 with those between 2009 and 2012 shows positive variations from 3.4 % for biology to 54.6 % for psychology [23].

In particular, Italy's scholars largely increased the number of papers published in "gold" open access (OA) journals published by for-profit scientific publishers of OA journals in which accepted articles are published after payment of an article processing charge. For example, restricting the analysis to original research articles published in English, Italy's scholars in 2023 published 97,701 articles indexed by the research database Scopus [24]. The first five journals publishing research by Italy's scholars in terms of number of articles were *International Journal of Molecular Sciences* (1218 articles), *Scientific Reports* (1,016), *Journal of Clinical Medicine* (925), *Applied Sciences* (761), and *Sustainability* (747). Said five journals are published by for-profit publisher (four by MDPI, a large publisher of gold OA journals only, and one by SpringerNature). In 2018, the number of original research articles published in English indexed by the same database were 77,354, and the first five journals publishing research carried out in Italy's scholars were *Scientific Reports* (910 articles), *PLOS One* (693), *Monthly Notices of The Royal Astronomical Socie*ty (538), *Astronomy and Astrophysics* (463), and *Physical Review D* (363). Three out of five of said journals were published by scholarly societies, one by a not-for-profit publisher of OA journals (Public Library of Science, PLOS), and one by SpringerNature.

### 3.4. Research excellence rewarding society

The findings above concerning the HRS refer to top scientists comprised in the 0.05 % of the ranked scholars worldwide, living and not living, encompassing over 30 million scholars in all fields. Some of them already engage with society in public debate. Chemist Gianfranco Pacchioni, for example, frequently gives public speeches on topics of general interest. Held in March 2021 in Italian, one such seminar dedicated to his book "*Scienza, quo vadis?*" was given online on a online video "channel" of Milan's Polytechnic [25]. Civil and Environmental Engineering scholar Anna Laura Pisello does the same, often presenting to the public through the general press her work with "fresh materials" (polymeric building materials reflecting solar energy) for the built environment [26]. Many other Italy's HRS frequently engage with society in related ways.

Besides engaging with society in public debate, Italy's top researchers may further reward society that supported their work through public research funding by providing students and young researchers with advanced education and student mentoring.

However, sometimes top researchers funded by grants/contracts have little assigned time to teaching and student mentoring. Sometimes top cited researchers are perceived by students as poor teachers [27]. Requiring substantial amounts of uninterrupted time for thinking, writing, and working both in the laboratory and with computers, research inevitably competes with teaching and student mentoring. Italy, in this respect, makes no exception. For example, student evaluation of teaching quality of Economics faculty at Salerno's University for six academic years from 2016/2017 to 2021/2022 (50,117 observations) was found to be inversely correlated to the number of publications of the professor in top journals (and also to the number of co-authors) [28].

Without quality teaching, however, universities become unable to attract and retain talented students and will not offer to society, the qualified graduates needed to conduct and improve work at widely different public and private organizations. Zurich ETH, one of the world's leading universities, is renowned for hosting some of the world's leading scholars in natural sciences, engineering, mathematics, architecture or management. The university demands to its scholars to dedicate plentiful time and efforts to teaching. For that it has developed a "Teaching policy" (the foundation for the development and evaluation of teaching at the institution), and a "Quality in teaching" document defining the quality criteria for curricula and courses, and the university's expectations of all professors and lecturers engaged in teaching [29]:

"Lecturers impart knowledge and skills that correspond to the cutting edge of science, plus personal and social competences. They train their students to be members of society, who think critically. Lecturers are conscious of their function as role models. As examiners, they orient themselves towards learning objectives and qualification profiles; in this context, they appraise not only knowledge, but also the understanding of interconnections, methodological skills and further competences [29]".

The level of the advanced education provided to PhD students by Italian universities in the best universities is generally high. For example, in the years 2011–2020, compared with the 7384 tenure-track faculty hired in Italy, American universities that grant PhDs hired 869 Italian PhD graduates who had got their doctorate at Italian universities during the same decade [30]. Still, there is plenty of room for improvement.

Italy's top scholars in the HRS ranking might therefore act as advocates to reform the evaluation of scholarship so that quality teaching is recognized and rewarded in the same way that excellent research currently is [31,32].

Finally, another way by which Italy's top scholars might benefit society (and the global scientific community) is through writing and publishing open, honest, and intellectually humble research reports. These kinds of reports avoid questionable research practices, unjustified interpretation, and include acknowledgment of limitations that "are owned and their consequences explicitly incorporated into the conclusions" [33]. From chemistry [34] to biology [35] and medical clinical research [36], on the other hand, researchers in numerous disciplines today including the "hard" sciences frequently use hyping "to glamorise, publicize, embellish or exaggerate their research" [35]. By refraining from hyping in their publications as well as in their public presentations, scholars found in excellent rankings have the opportunity to guide fellows, students and researchers to much-needed practice of intellectual humility in science [33].

For example, discussing the limitations of the present study, when conducting the analysis of Italy's HRS we identified in June 2024 some errors in scholar affiliations that were reported in the preprint of the study published online (on ResearchGate) shortly afterwards. The research database corrected the erroneous affiliations [37] and now correctly reports for example the 148 HRS, prior five years [2]. Another intrinsic limitation, common to all scholar rankings, is that being based on publication records, they provide evidence that top scholars are affiliated with institutions providing substantial more time for research writing than for teaching, and service work [38].

## 4. Conclusions

We agree with economist Heimberger: regardless of the difficult Italy's social and economic situation highlighted in the introduction [10,11], there has been too little critical reflection on how Italian policymakers could develop a credible approach to end Italy's decline and opening up a positive long-term economic development perspective for Italy [9]. Such a paucity of critical reflection includes the public discourse on scientific research in Italy, and even more that on scientific excellence in the Mediterranean country. Relying on data concerning exceptional scholars (HRS) recently published by research database ScholarGPS, we have investigated excellence in Italy's scientific research with reference to HRS in specific fields, disciplines, specialties and affiliations on both lifetime and last 5-year bases.

Results are informative in many aspects, including in comparison to other nations. Indeed, recently a similar investigation of world's top scientists across disciplines unveiled that Greece, when taking into consideration Greek scientists working abroad, would rank amid the top 10 countries in nearly half of scientific disciplines used to classify research [39]. Similarly, ranking of academic institutions worldwide based on the number of HRS was lately published [40].

With 148 scientists in the HRS ranking, lifetime, Italy has a substantially lower number of HRS than France (220 HRS). Yet, when it comes to the last 5-year ranking, Italy has 146 scholars in the ranking whereas France has only 88 HRS. For comparison, France has a gross domestic product 21 % higher than Italy (2565 billion EUR for France in 2023 [41] *vs.* 2085 billion for Italy [42]) and a population 16 % larger than Italy (68.4 million inhabitants on January 1, 2024 in France *vs.* 58.85 million in Italy). Overall, only 8 countries in the world (USA, China, Great Britain, Germany, Australia, Canada, Iran and India) have more HRS, last-5 year, than Italy.

Rebuilding a strong Italian economy based on advanced technology as well as on better management practices, will rely also on the contributes of its top scholars. The emergent economy will see societies overcome the issues generated by the knowledge economy [43], including deindustrialization driven by unwise decisions for manufacturing offshoring. As such, it will require wise management and wise leadership of the organizations comprising it [44]. This in turn requires managers and entrepreneurs with an expanded cultural background and education unifying formerly separated natural and human sciences [45]. Italy's top scholars might therefore

assist policy makers in devising new cross-disciplinary curricula to be employed in new advanced management and advanced schools. Seen from this perspective, a critical reflection on the recent outcomes of a new AI-based algorithm used to rank Italy's past and present top researchers [12] becomes an opportunity to address the aforementioned lack of critical reflection on how "to develop a credible approach to open up a positive long-term development perspective for Italy" [9]. Subsequent research informing the public discourse on Italy's research might address the research performance of Italy's universities and public research bodies.

## CRediT authorship contribution statement

**Rosaria Ciriminna:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Cristina Della Pina:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Mario Pagliaro:** Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

## Ethics statement

Not applicable.

## Data availability statement

Data supporting the findings of this study can be accessed online at https://doi.org/10.1016/j.heliyon.2024.e41335.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

R.C. and M.P. thank Ministero delle Imprese e del Made in Italy for funding the article processing charge of this study under the Piano Operativo della Ricerca "Ricerca e sviluppo sull'idrogeno" financed by the EU NextGenerationEU - M2C2 Investment 3.5, in the framework of the project PNRR Ricerca e Sviluppo sull'Idrogeno 2022–2025–Accordo di Programma "Idrogeno" (PRR. AP015.017.002), "Obiettivo 1 - Produzione di idrogeno verde e pulito", "LA 1.1.6 - Sviluppo di materiali e component non contenenti materiali critici per elettrolizzatori anionici (AEM) operanti anche ad elevata pressione differenziale".

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e41335.

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