Short-term effects of non-competitive funding to single academic researchers

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Abstract

Research funding is essential to promote the scientific activity of researchers and the dissemination of their results. Simplifying, funding schemes can be classified in two categories – *competitive* and *non-competitive* – with several corresponding advantages and shortcomings, which are widely discussed in the scientific literature.

The researchers of Politecnico di Torino (i.e., one of the major Italian technical universities) have recently been funded through a non-competitive research funding, consisting of 14k€ for every single researcher in each of the last three years (i.e., from 2017 to 2019), for a total of 42k€. This somewhat unusual initiative – also called "diffused funding" (DF) – represents an important opportunity to investigate the effects of the relatively large allocation of non-competitive funding to single researchers. In this regard, this paper investigates the effects of the DF on the researchers' scientific output, according to four dimensions of analysis: *publishing productivity*, *publishing diffusion/impact*, *journal reputation*, and *international research relations*. Preliminary results do not indicate any improvement in the publication output, at least in the short term.

Keywords: Non-competitive funding, Short-term effects, Publishing productivity, Publishing diffusion/impact, Journal reputation, International research relations, Time-series normalization, Politecnico di Torino.

Introduction and literature review

There is no doubt that (public and private) funding is essential to encourage the constant and effective evolution of the scientific research and the dissemination of its results (Jacob and Lefgren, 2011). Different funding schemes can result from the combination of (at least) four factors:

1. *Funding body.* We distinguish between *non-commercial* – e.g., public government bodies, research councils, European commissions, etc. – and *commercial* – e.g., private companies or industrial consortia/districts, which usually propose research topics.
2. *Funding recipients.* We distinguish between individual researchers and research institutions – such as entire universities, departments, groups of researchers, etc. – who generally have some autonomy in allocating funds internally.
3. *Allocation of the funds.* We distinguish between *non-competitive* allocation (or *block* funding) and *competitive* allocation, e.g., based on (i) submission of research projects/proposals and/or (ii) previous scientific production of candidates. Although there are no general schemes, non-competitive funding is typically provided by the government and intended for public research institutions to cover the salaries of research staff, operating costs and maintenance of infrastructure (e.g., classrooms, laboratories,

libraries, etc.) (HFFCE, 2017). It is well known that non-competitive funding is fundamental for the stability and autonomy of entire research institutions (Abramo et al., 2011; Hicks, 2012).

4. *Spending constraints.* For example, time constraints, which impose the use of funds within a certain period, or constraint on the type of expenditure (e.g. for scholarships, support material for teaching, laboratory equipment, consumables, etc.).

The different combination of these four factors may lead to very different funding schemes, each with its own strengths and weaknesses that are often difficult to predict.

In the last three-to-four decades, there has been a tendency in many countries to make public funds increasingly competitive, combined with the gradual diffusion of national exercises for research evaluation (Wang et al., 2018). E.g., in Italy, the public funds that are allocated by the government to public universities include a (non-competitive) fixed share and a (competitive) merit-based share, whose percentage incidence tends to gradually increase over time: 13% in 2013, 22% in 2017, etc. (Abramo and D'Angelo, 2015; Franceschini and Maisano, 2017; Demetrescu et al., 2019).

Due to the economic crisis, Italian universities have suffered a certain decrease in public funding over the last decade, only partly compensated by the increase in private funding (Horta et al., 2008; Abramo et al., 2011; Muscio et al., 2013). Universities and research institutions located in economically/industrially flourishing areas have been able to "exploit" this kind of compensation, certainly more than those in depressed areas (Mateos-González and Boliver, 2019).

Returning to the different funding schemes, the scientific literature contains many debates – sometimes very passionate – on their presumed effectiveness (Jacob and Lefgren, 2011; Van Den Besselaar et al., 2017; Wang et al., 2018). Nevertheless, there is often a lack of data on inputs and outputs over a reasonably long period to assess the (un)success of a certain funding scheme. Geuna and Martin (2003) provided a qualitative discussion of the (presumed) advantages and shortcomings of two antithetical research funding schemes: i.e., *competitive* versus *non-competitive*, as shown in Table 1.

Analyzing Table 1, it would seem desirable – for a generic research institution – to achieve the right mix of competitive and non-competitive funds, with the aim of maximizing the benefits while minimizing the disadvantages. Unfortunately, there are no general rules and the success of a certain research funding scheme is often conditioned by various exogenous factors, such as the socio-economic context, the "health" of the recipient institution, the level of bureaucracy, etc. (Laudel, 2006). The difficulty in studying the (positive and negative) effects of a certain funding policy is also linked to the following limitations:

Table 1. Advantages and drawbacks of two alternative approaches to university research funding: *competitive* and *non-competitive*. Adapted from (Geuna and Martin, 2003).

	Advantages	Drawbacks
Competitive funding	• "Meritocratic" in that it links resources to performance, rewarding good research. • Strong incentive to improve individual as well as institutional performance. • Competition may lead to increased efficiency, ineffective research identified and cut. • Encourages research to be properly completed and written up for wider dissemination. • Provides public accountability for government funds invested in research. • Encourages more explicit/coherent research strategy on part of department or institution. • Provides mechanism for linking university research to government policy (e.g., to shift priorities). • Concentration of resources may enable best departments to compete with world leaders.	• High cost and labour intensity (whether peer review or indicator-based) for universities and evaluating agencies. • May encourage "homogenization" of research and universities – i.e., decrease in diversity and experimentation. • May discourage more innovative and risky research. • Encourages "publication inflation" (e.g., "salami publishing") and other "game playing" (e.g., with indicators) – i.e., "looking good" rather than necessarily doing better. • May encourage traditional "academic" research at expense of research linked to society's needs. • Tends to separate research from teaching, with lower priority for teaching. • Rewards past performance (not current one or future potential), reinforcing research elite/status quo and encouraging over-concentration. • May lead to excessive government influence/"interference" in university research.
Non-competitive funding	• Low cost to administer. • Provides departments with "seed corn" funds to invest in new people/research areas. • Provides "space" for long-term research and scholarship. • Encourages diversity in research. • Enables academics at any university (not just an elite few). • To get involved in research. • Encourages integration of teaching and research so can exploit synergy between them. • Protects autonomy of institutions and individuals.	• Little direct incentive to improve research performance (whether individual or institutional) – may lead to stagnation. • May give excessive power to officials who distribute core funding within institution. • Little public accountability for funds (notionally) provided for research – may encourage "ivory tower" research with no social or other relevance. • May reinforce public stereotype that some academics are "lazy". • May be little or no correlation between student numbers and level of research effort by department. • Distribution of resources/effort may bear little relationship to stated government policy. • Spreading resources evenly but thinly may discourage to compete with world-leading institutions.

- The data available are often limited and incomplete;
- The difficulty of defining indicators/proxies that effectively represent important aspects of researchers' activities (e.g., scientific productivity, teaching activity, technology transfer, international scientific reputation, etc.).

It is therefore not surprising to see contradictory opinions on funding policies. For example, Butler (2003) states that the growth of competitive funds encourages productivity, to the detriment of scientific impact. Van Den Besselaar et al., (2017) deny the previous study, showing that the increase in productivity generally "goes hand in hand" with the increase in the scientific impact.

Some authors show that it is more appropriate to allocate funds to "best performers" exclusively and not to a broad base of potential users, in order to maximize results (Auranen and Nieminen, 2010). Other authors show that the excessive concentration of funds can be counterproductive, encouraging the adoption of variable/adaptive methods of selecting the funding recipients, e.g., methods based on an initial recipient selection (with a corresponding preliminary allocation) followed by increasingly stringent recipient selections (and corresponding funding allocations), depending on the results obtained (Reardon, 2007; Fedderke and Goldschmidt, 2015).

Some studies show that – to the right extent – non-competitive funding makes researchers more autonomous and "relaxed", stimulating their creativity and – indirectly – their productivity (Bolli and Somogyi, 2011); in fact, the obsession to seek competitive funds actually absorbs a lot of physical and mental energy. Despite this, there is evidence that the excess of autonomy can result in inefficiency (Wolszczak-Derlacz, 2017).

This paper focuses on an uncommon non-competitive funding initiative involving Politecnico di Torino, hereinafter abbreviated as “PoliTO”. PoliTO is an Italian public technical university of good (national and international) reputation, which is composed of about 900 tenured researchers (including assistant/associate/full professors) and provides numerous graduation courses – in Engineering and Architecture mainly – for over 34,000 national/international students (see http://www.polito.it, last accessed on January 2020).

Despite the last-decade period of dire straits of Italian universities, which have experienced a significant decline in terms of public funding (Abramo et al., 2011), the PoliTO cash registers have recently come to have a substantially high liquidity. This liquidity is due to a mixture of causes:

1. In recent years, there has been a massive turnover of research staff, characterized by the large retirement of many senior full professors (with expensive salaries), partly compensated by the recruitment of young researchers (with significantly lower salaries).
2. In the last ten years, the number of students enrolled at PoliTO has been constantly growing, with a consequent increase in revenue, due to tuition fees and the (non-competitive) fixed share provided by the government. On the other hand, the size of the research staff is almost unchanged.
3. In the five-year period 2011-2015, the salaries of all Italian university researchers were temporarily blocked[1], because of a government decree aimed at safeguarding public accounts, trying to contrast the recent international economic crisis. It is roughly estimated that this measure allowed PoliTO to save more than 2M€ per year for five years.
4. Following the recent national research evaluation exercises – i.e., the so-called VQR 2004-2010 and VQR 2011-2014 (Abramo and D’Angelo, 2015; Franceschini and Maisano, 2017) – PoliTO has received a relatively high share of government funding on account of the good results obtained.
5. The university planned to make significant investments in infrastructure for redeveloping some unused public infrastructure (in the city of Turin), with the aim of obtaining new space for teaching activities (e.g., classrooms and laboratories). As a consequence, PoliTO had begun to set aside a certain amount of investment capital. For exogenous reasons, the university then gave up making these investments.

The governmental bodies of PoliTO, with the predominant role of the Board of Administrators[2] (BoA) and the (former) Chancellor, decided in 2016 to use (part of) this liquidity to finance some initiatives for promoting research and teaching activities. A portion was allocated to departments to finance new teaching

[1] As a rule, salaries are progressively increased depending on the length of service, with two-yearly increments.
[2] In Italian, “Consiglio di Amministrazione”.

projects (e.g., improvement of teaching laboratories, acquisition of new hardware/software resources, etc.), while another portion was allocated to departments to finance internal research projects.

In addition, a very large portion of the aforementioned liquidity was allocated directly to individual researchers. Precisely, around the middle of the year 2016, the BoA decided to assign a "lump sum" of 14k€ to each tenured researcher of the PoliTO, to support his/her research activities for the year 2017, without particular constraints, neither on the type of expenditure nor in terms of time. Because of its universality, this annual funding was denominated "diffused funding"[3] and will henceforth be abbreviated as "DF". The first DF was made accessible since 1st January 2017; the same funding was repeated for each of the following two years, allocating further 14k€ in the year 2018 and 14k€ in the year 2019, for a total of 42k€ to each tenured researcher in three consecutive years.

This substantial non-competitive funding policy is unusual in the current Italian scene and PoliTO researchers are undoubtedly privileged compared to their national counterparts. In fact, we are not aware of any initiatives such as DF in other Italian universities, at least for the moment.

The exceptionality of the initiative is even more evident considering that Italian universities are tendentially centralized and with limited autonomy, which can be extended at the level of individual researchers (Abramo et al., 2013). In fact, the annual non-competitive share of funding that Italian public universities usually allocate to individual researchers is around 500-1000 € per year, i.e., one-two orders of magnitude lower than the DF (Muscio et al., 2013)!

The authors believe that the DF plays a role of considerable importance for those dealing with policies for allocating research funds. In fact, this initiative represents an important opportunity to investigate the effects of the substantial allocation of non-competitive funding to individual researchers.

From the above considerations, some interesting research questions arise: "What are the short-term effects of the DF initiative on the scientific output of PoliTO researchers?" and "Are there significant differences between PoliTO researchers and their counterparts who have not benefited from the DF?".

The aim of this paper is to compare the scientific output of PoliTO researchers with that of their peers at the national level, trying to provide plausible answers to the previous questions. From a methodological point of view, a sample of PoliTO researchers will be selected, comparing their scientific performance with that of analogous researchers from other Italian universities. The comparison will be made considering a time window between 2008 and 2019, with special attention to the last three years (i.e., 2017 and 2019) in which PoliTO researchers have benefited from the DF.

The scientific performance will be evaluated considering four different dimensions: (1) "Publishing productivity", (2) "Publishing diffusion/impact", (3) "Journal reputation", and (4) "International research

[3] In Italian, "finanziamento diffuso".

relations". Each of the above dimensions will be represented through appropriate indicators/proxies. The authors are aware that there are other important dimensions that are not strictly focused on scientific publications (e.g., participation in projects, teaching or technology transfer activities), for which the collection of objective and complete data is far more difficult.

The remainder of this paper is organized into three sections. The "Methodology" section describes in detail the data collection/analysis and the indicators used to represent the four analysis dimensions. The "Results" section details the results of the analysis, providing motivated answers to previous research questions. Finally, the "Discussion" section summarizes the original contributions of this research, highlighting possible implications, limitations and ideas for future research.

Methodology

As anticipated in the previous section, the objective of this research is comparing the scientific output of PoliTO researchers and that of the researchers from other Italian public universities (hereinafter abbreviated as "Other Universities" or, even more briefly, "OU"), before and after the implementation of the DF. Consistently with this objective, it was decided to make a comparison between groups of researchers in the same disciplines.

In Italy, each tenured researcher from public universities belongs to one-and-only-one specific *discipline*[4], around 370 in all (Abramo et al., 2011; 2013; Franceschini et al., 2013). A complete list accessible at (MIUR, 2020a).

Although the researchers of PoliTO (and other technical universities) are scientifically more homogeneous than those belonging to generalist universities, they can be associated with a number of different disciplines, with significant differences in terms of propensity to publish and cite (Franceschini and Maisano, 2014). Among the various PoliTO tenured researchers, we have selected those belonging to the sixteen disciplines reported in Table 2. We have limited the selection to researchers that were active in the entire period from 2010 to 2019, thus excluding changes in the staff number (N), due to staff retirements, new hires, transfers, etc.. The last two columns of Table 2 report the N values of the PoliTO researchers and those of researchers from the OU. The resulting sample of PoliTO tenured researchers (i) covers more than 25% of all PoliTO researchers and (ii) includes several characteristic disciplines of the Engineering field. Researchers were identified through public directories (MIUR, 2020b).

[4] In Italian, "Settore Scientifico Disciplinare", which means "Scientific and Disciplinary Sector".

Table 2. Summary of the researchers (from PoliTO and the other universities) considered in the analysis. Researchers are divided into sixteen disciplines.

Discipline	Abbreviation	Staff number (N)	
		PoliTO	Other universities
A. Chemical foundations of technologies	CHIM/07	9	132
B. Physics of matter	FIS/03	16	288
C. Structural mechanics	ICAR/08	15	240
D. Thermal engineering and industrial energy systems	ING-IND/10	12	116
E. Applied mechanics	ING-IND/13	23	131
F. Mechanical design and machine construction	ING-IND/14	21	119
G. Design methods for industrial engineering	ING-IND/15	4	72
H. Manufacturing technology and systems	ING-IND/16	17	110
I. Industrial mechanical plants	ING-IND/17	5	125
J. Materials science and technology	ING-IND/22	20	163
K. Excavation engineering and safety	ING-IND/28	5	13
L. Electrical engineering	ING-IND/31	12	146
M. Business and management engineering	ING-IND/35	6	154
N. Telecommunications	ING-INF/03	24	256
O. Information processing systems	ING-INF/05	40	534
P. Mathematical analysis	MAT/05	15	584
	Total	**244**	**3183**

Subsequently, the publication output of these researchers was downloaded from the Scopus database. The risk of analysis distortions due to homonymies or other ambiguities is minimized by the database query method, which includes the Scopus IDs of researchers. The documents analysed consist of articles from international journals and conference proceedings indexed by Scopus, which were published in the twelve-year period from 2008 to 2019. For each combination of discipline and year, some indicators – normalized with respect to the staff number – were determined to represent the four dimensions of interest; Table 3 provides a brief description of these indicators.

It can be noticed that the indicators representing the dimensions (1), (2) and (4) are normalized by dividing a certain variable (respectively P, C or F) by N, in order to allow comparison between groups of researchers of different size.

For each of the sixteen disciplines and each of the above indicators, a pair of 2008-2019 time series were determined: the one related to PoliTO researchers and the one related to the researchers of the "OU". Before comparing these pairs of time series, it is necessary to reflect on some "technical" problems:

- The propensity to publish/cite is not necessarily the same for all the disciplines considered (Moed, 2010b; Franceschini and Maisano, 2014).
- Regardless of the discipline, the propensity to publish/cite tends to gradually increase over time. This "inflationary" behaviour is partly related to the increasing pressure to publish and partly related to the constant expansion and growth of the scientific community; for more information, see (Petersen, 2018).
- Older publications have had more time for accumulating citations than the more recent ones.

Table 3. Indicators normalized with respect to the staff numbers (*N*) related to the four dimensions of interest (see Table 2).

Dimension	Indicator	Short description
(1) Publishing productivity	*P*/*N*	The indicator – given by the ratio between the number of journal articles (*P*) by a certain group of researchers and the number of researchers themselves (*N*) – expresses the average level of productivity *per capita* for a certain year.
(2) Publishing diffusion/impact	*C*/*N*	The indicator – given by the ratio between the total number of citations (*C*) accumulated at the moment of the analysis (i.e., January 2020) by the journal articles of a certain group of researchers and the number of researchers themselves (*N*) – expresses the average level of impact/diffusion *per capita* for a certain year.
(3) Journal reputation	*Avg. SNIP*	The indicator – which corresponds to the average value of the *SNIP*(*) associated with the journal articles issued in a certain year – is used as a proxy of the reputation of the journals publishing the articles of a group of researchers. As an alternative to *SNIP*, one could use other pre-calculated journal indicators for the Scopus database, such as *CiteScore* (similar to the popular *ISI Impact Factor* of the "competing" Web of Science database) or the *SJR* (Scimago Journal & Country Rank).
(4) International research relations	*F*/*N*	The indicator – given by the ratio between the number of conference articles indexed by Scopus (*F*) by a certain group of researchers and the number of researchers themselves (*N*) – depicts the average presence to conferences *per capita*, for a certain year. The authors are aware that the conferences indexed by the Scopus database represent a relatively small portion of all the international conferences.

(*) We remark that *SNIP* is an annual field-normalized indicator for ranking scientific journals by Moed (2010a). *SNIP* values related to a particular journal and reference year can be obtained by querying an online application (based on the Scopus database), freely available at http://www.journalindicators.com (last accessed on January 2020). Since the *SNIP* values were not yet available at the time of the analysis for the journals published in 2019, the 2018 *SNIP* values were used.
It is worth remarking that *SNIP* is not available for all the journals indexed by Scopus; articles from journals without *SNIP* were excluded. This operation should not distort the analysis, since the portion of articles excluded is quite stable – usually around 6-8% – for the different groups of papers analysed.

A further year-by-year normalization of the four indicators in Table 3 was introduced; precisely, each indicator referring to the PoliTO researchers (generically indicated as $x^{(PoliTO)}$) was compared to the corresponding indicator referring to the researchers in the other universities (generically indicated as $x^{(OU)}$), according to the following ratio model:

$$y = \frac{x^{(PoliTO)}}{x^{(OU)}}, \qquad (1)$$

Values of y higher/lower than the unit respectively indicate that the performance of PoliTO researchers in the year of interest is higher/lower than that of their counterparts in the rest of the Italian universities. The year-by-year normalization in Eq. 1 was introduced to overcome the aforementioned "technical" problems of comparability among disciplines.

Table 4 summarizes the indicators after this second normalization for each of the four dimensions of interest. As previously described, the normalization is accomplished in two stages: (i) normalization by staff number (if applicable), and then (ii) year-by-year normalization with respect to the OU.

The choice to consider the indicators in the twelve-year period from 2008 to 2019 is motivated by the following reasons:

- Since the indicators in the first nine years (i.e., 2008-2016) are not influenced by the DF, they will allow to estimate the "natural performance"[5] of PoliTO researchers with respect to their counterparts in the OU.
- This estimate will constitute a sort of reference for assessing whether in the last three years (i.e., 2017-2019, which are potentially influenced by the DF) PoliTO researchers have been performing differently than in the nine previous years.

Table 4. Indicators normalized with respect to *N* and then with respect to the OU. These indicators depict the relative performance of groups of PoliTO researchers with respect to counterparts in the OU.

	Dimension	Indicator	Short description
(1)	Publishing productivity	$\frac{P^{(PoliTO)}/N^{(PoliTO)}}{P^{(OU)}/N^{(OU)}}$	The normalized indicator compares – for a certain discipline and year – the average number of journal articles *per capita* of PoliTO researchers with that of the counterparts in the OU.
(2)	Publishing diffusion/impact	$\frac{C^{(PoliTO)}/N^{(PoliTO)}}{C^{(OU)}/N^{(OU)}}$	The normalized indicator compares – for a certain discipline and year – the average number of citations *per capita* accumulated by the journal articles of PoliTO researchers with that of the counterparts in the OU.
(3)	Journal reputation	$\frac{Avg.SNIP^{(PoliTO)}}{Avg.SNIP^{(OU)}}$	The standardised indicator compares – for a certain discipline and year – the *Avg. SNIP* value of the journal articles of PoliTO researchers with that of the counterparts in the OU.
(4)	International research relations	$\frac{F^{(PoliTO)}/N^{(PoliTO)}}{F^{(OU)}/N^{(OU)}}$	The normalized indicator compares – for a certain discipline and year – the average number of conference articles *per capita* of PoliTO researchers with that of the counterparts in the OU.

The authors are aware that three years is a relatively limited period to evaluate possible effects of the DF, considering the production time of scientific publications and the maturation time of the respective citations (Van Den Besselaar et al., 2017; Bar-Ilan and Halevi, 2018). Nevertheless,

- the production of scientific publications in the Engineering field is faster than in other fields (Moed, 2010b);
- although the DF has been disbursed since 2017, the initiative was officially approved around mid-2016. It therefore seems reasonable to assume that this information may have influenced the behaviour/attitude of PoliTO researchers even before 2017, when they actually had access to the funding capital.

Results

Table 1 contains the size (*N*) of the groups of researchers (of PoliTO and the OU) considered in the analysis, divided by discipline. The Scopus database was queried, extracting the data concerning the above-mentioned groups of researchers and constructing the indicators introduced in the section "Methodology", for each of the four dimensions of interest.

Table E.1 (in the Electronic Supplementary Material) contains the results related to the dimension (1) "Publishing productivity". Precisely:

[5] The "natural performance" may be defined as the performance that PoliTO researchers tended to exhibit before benefiting from the DF.

- Table E.1(a) contains the time series of the annual *P* values for each discipline;
- Table E.1(b) contains the time series related to the indicators normalized with respect to *N* (see their description in Table 3), for each discipline;
- Table E.1(c) contains the time series related to the indicators normalized with respect to *N* and with respect to the OU (see Table 4), for each discipline.

For the four disciplines, the productivity of PoliTO researchers is generally in line with that of the counterparts in the OU. As an example, consider the graph in Figure 1, about the discipline "B. Manufacturing technology and systems". It can be noted that the PoliTO profile is a little more nervous than the corresponding OU profile; this is not surprising, considering the significantly lower number of PoliTO researchers, which makes the annual estimates of their productivity *per capita* more dispersed than that of the corresponding researchers in the OU (see also the column with "St. Dev." in Table E.1(b)).

We can also appreciate a certain inflationary phenomenon that leads to a gradual growth in publishing activity over time, in line with what is documented in (Petersen, 2018). Table E.1(c) (in the Electronic Supplementary Material) also shows systematic differences between researchers belonging to different disciplines: for example, PoliTO researchers in the discipline "L. Electrical Engineering" seem to perform significantly better than their counterparts in the OU (see the data normalized with respect to *N* and with respect to the other universities, which are systematically higher than the unit), while PoliTO researchers in the discipline "I. Industrial mechanical plants" tend to perform worse.

The considerations seen for the dimension (1) "Publishing productivity" can be extended to the other dimensions, as evidenced by Table E.2 (in the Electronic Supplementary Material) for dimension (2) "Publishing diffusion/impact", Table E.3 (in the Electronic Supplementary Material) for dimension (3) "Journal reputation", and Table E.4 (in the Electronic Supplementary Material) for dimension (4) "International research relations". Again, the initial data were normalized in two stages: (i) based on the staff number (*N*) and (ii) with respect to the OU. The only exception is the indicator "*Avg. SNIP*", which represents the dimension (3) "Journal reputation": being this indicator *size-independent*, the first normalization stage is not necessary (Franceschini et al., 2013).

Inflationary phenomena can also be observed for dimensions (3) and (4)[6], leading to a gradual increase in productivity and citation impact. See for example the graphs in Figures 1(3) and 1(4), which show the curves related to the above dimensions for discipline "B. Manufacturing technology and systems". Similar results can be observed for the other disciplines.

[6] As for dimension (2), this phenomenon is partly hidden since the so-called "citation inflation" is compensated by the lower time available for citation accumulation of the more recent journal articles.

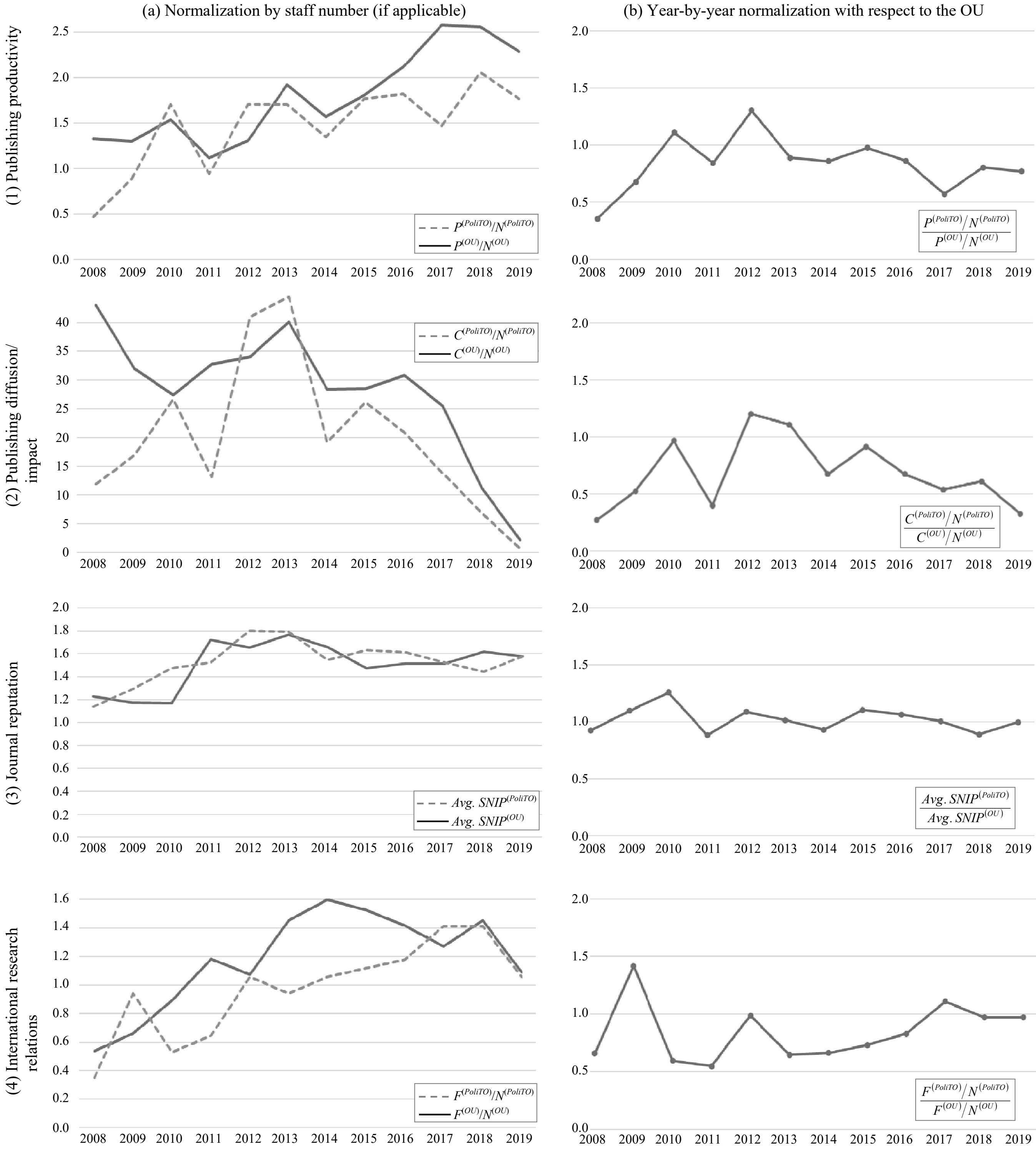

Figure 1. Graphic representation of the (normalized) data in Tables E.1, E.2, E.3 and E.4 (in the Electronic Supplementary Material), with reference to the discipline "B. Manufacturing technology and systems".

The year-by-year normalization with respect to the OU, introduced in Tables E.1(c), E.2(c), E.3(c) and E.4(c) (in the Electronic Supplementary Material), makes it possible to "purge" the aforementioned inflationary phenomena obtaining deflated time series with regard to all of the sixteen disciplines considered (i.e., A, B, C, ..., as shown in Table 2).

For each analysis dimension, it is finally possible to aggregate the time series relating to the sixteen individual disciplines into a single (aggregated) time series, depicting the overall performance of PoliTO researchers from the perspective of the dimension of interest. The aggregation can be made through their weighed sum, using as weight the staff number of the PoliTO researchers for a certain *d*-th discipline ($N_d^{(PoliTO)}$):

$$w = \frac{\sum_{\forall d} y_d \cdot N_d^{(PoliTO)}}{\sum_{\forall d} N_d^{(PoliTO)}}, \tag{2}$$

w being the aggregate value for a certain year and the "*d*" subscript denoting a certain discipline ($d \in \{\text{A, B, C, D, E, F, G, H.I, J, K, L, M, N, O, P}\}$, as illustrated in Table 2).

The results of the aggregated indicators for the four dimensions of interest are reported in the last lines of Tables E.1, E.2, E.3 and E.4 (in the Electronic Supplementary Material), and will be further recalled in Table 6. Let us now focus on the corresponding aggregated-indicator charts in Figure 2; it can be noticed that – being purged of the above-described inflationary effects too – they show a (presumably) random trend.

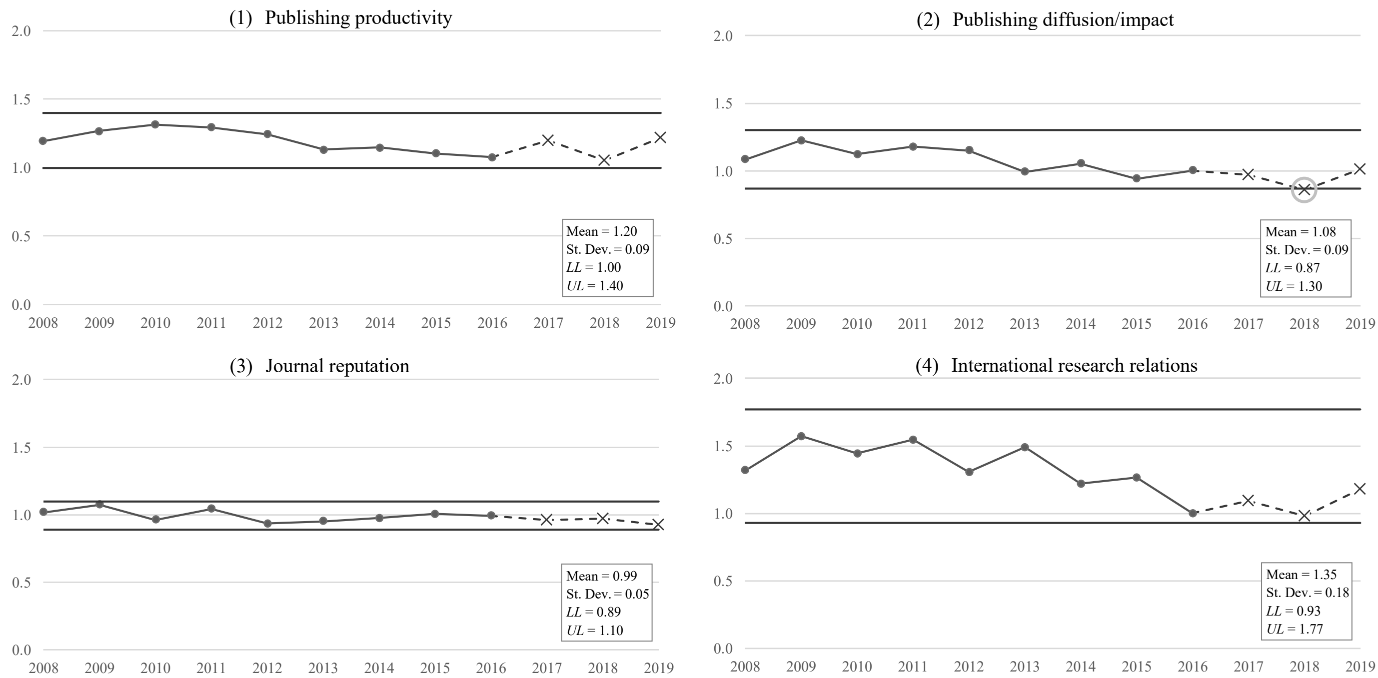

Figure 2. Charts related to the (normalized) time series related to the four analysis dimensions. Numerical data are contained in the Tables E.1(c), E.2(c), E.3(c) and E.4(c) (in the Electronic Supplementary Material).

To confirm this, Table 5 contains the results of the Kendall's Turning Point test for each of the four dimensions considered (Kendall, 1973; Brockwell and Davis, 2016). This test can be performed to verify the randomness of the time series, using the data between 2008 and 2016, since these years are not influenced by the DF and therefore depict the "natural" overall performance of PoliTO researchers. Precisely, for each time series, the number of so-called *turning points* observed (T_p, i.e. the number of local *maxima*/*minima*, excluding the two endpoints) has been determined and compared with a corresponding expected value, in the hypothesis that the time series is random.

For the first three time series, the null hypothesis of randomness cannot be rejected at a confidence level of 95% (p-values > 0.05); for the last time series – which concerns the dimension (4) "International research relations" – the randomness is doubtful (p-value = 0.039), due to the relatively high number of turning points; this result is somehow affected by the relatively low number of data, therefore it should be considered with prudence (Ross, 2009).

Table 5. Results of Kendall's Turning Point test for testing the randomness of the four time series in Figure 2, considering the data from 2008 to 2016.

Dimension	*maxima*	*minima*	T_p	n	z	p
(1) Publishing productivity	2	1	3	9	-1.474	0.140
(2) Publishing diffusion/impact	3	3	6	9	1.180	0.238
(3) Journal reputation	3	2	5	9	0.295	0.768
(4) International research relations	4	3	7	9	2.064	0.039

Note:

- The number of (local) *maxima*/*minima* are determined excluding the extremes of the time series.
- T_p is the number of so-called *turning points*, i.e., T_p = *maxima* + *minima*.
- $n = 9$ is the number of points taken into account for each time series (i.e., from 2008 to 2016).
- The test statistic is $z = \frac{T_p - \frac{2 \cdot n - 4}{3}}{\sqrt{\frac{16 \cdot n - 29}{90}}}$ (Kendall, 1973; Brockwell and Davis, 2016).
- The p-value of the two-tailed test is defined as $p = 2 \cdot [1 - \Phi(|z|)]$ (Kendall, 1973; Brockwell and Davis, 2016).

Focussing on the results related to the years 2017-2019, which are potentially influenced by the DF, it would seem that there is no apparent increase in the performance of PoliTO researchers compared to their counterparts in the OU for all the dimensions of interest. In several cases, it actually seems that there is a decreasing trend.

The previous trends can be examined more rigorously by means of a statistically sound test. For each of the four time series, it is constructed a 95% confidence interval, which should include the realizations of a random variable with $w \sim N(\mu, \sigma^2)$, μ and σ^2 being both unknown. To estimate the "natural performance" of the PoliTO researchers, we only used the data in the nine-year period 2008-2016, since they are certainly not influenced by the DF.

Compatibly with the available data, the best possible estimator of μ is:

$$\hat{\mu} = \overline{w} = \frac{1}{9} \cdot \sum_{i=2008}^{2016} w_i \;. \tag{3}$$

Since the sample of data is small (in fact, it includes only nine observations), the sample variance

$$s^2 = \frac{1}{9-1} \cdot \sum_{i=2008}^{2016} \left(w_i - \overline{w}\right)^2 , \tag{4}$$

systematically underestimates σ^2 (Ross, 2009). The $\overline{w}$ and s values related to the four aggregated time series are reported in Table 6 (see the columns "Mean" and "St. Dev." respectively). A 95% confidence interval for w – delimited respectively by a lower limit, (LL) and an upper one (UL) – can be constructed using the Student t distribution:

$$\begin{aligned} UL &= \overline{w} + t_{\nu,1-\frac{\alpha}{2}} \cdot s \\ LL &= \overline{w} - t_{\nu,1-\frac{\alpha}{2}} \cdot s \end{aligned} , \tag{5}$$

being $\nu = 9–1 = 8$, $\alpha = 5\%$ and therefore $t_{\nu,1-\frac{\alpha}{2}} = t_{\nu,97.5\%} = 2.306$.

The fact that the above symmetrical confidence intervals are reasonable is corroborated by the fact that the null hypothesis that time series are normally distributed (in the period 2008-2016) cannot be rejected, as illustrated in Figure A.1 (see the section "Additional statistical tests" in the Appendix).
For each of the analysis dimensions, the resulting values of LL and UL are reported in the last two columns of Table 6 and graphically represented in the graphs in Figure 2.

Table 6. Aggregated time series related to the four dimensions of analysis and relevant statistics.

Dimension	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean[†]	St. Dev.[†]	*LL*	*UL*
(1) Publishing productivity	1.19	1.27	1.31	1.29	1.24	1.13	1.15	1.10	1.07	1.20	1.05	1.22	1.20	0.09	1.00	1.40
(2) Publishing diffusion/impact	1.08	1.22	1.12	1.18	1.15	0.99	1.05	0.94	1.00	0.97	0.86	1.01	1.08	0.09	0.87	1.30
(3) Journal reputation	1.02	1.07	0.96	1.04	0.93	0.95	0.97	1.00	0.99	0.96	0.97	0.93	0.99	0.05	0.89	1.10
(4) International research relations	1.32	1.57	1.44	1.54	1.30	1.49	1.22	1.27	1.00	1.09	0.98	1.18	1.35	0.18	0.93	1.77

(†) These statistics have been calculated taking into account only the data in the period not affected by the DF (i.e., from 2008 to 2016).

It can be noticed that all the time series are contained in these limits in the period 2008-2016, reinforcing the hypothesis that they do not show any non-random trend. More interestingly, even the data for the years 2017, 2018 and 2019 are generally within the relevant confidence-interval limits. This means that, in general, there are no statistically significant differences between the results of the PoliTO researchers in the last three years (2017-2019) with respect to the previous nine years (2008 to 2016), for each of the analysis dimensions. In other words, it seems that there are no significant effects of the DF on the dimensions of interest. However, observing the aggregated time series related to the dimension (2) "Publishing diffusion/impact", the result for the year 2018 is slightly lower than the LL (see the circled point in Figure 2(2)). This would mean that the only statistically significant effect of the DF is a slight reduction in this analysis dimension for the year 2018, with respect to the period 2008-2016.

The fact that the DF did not produced any significant increase in any of the four dimensions of interest is corroborated by a further randomness test (i.e., Kendall's Turning Point test at 95%); see Table A.1 in the section "Additional statistical tests" (in the Appendix). This other test seems to exclude the presence of non-random trends for the entire period 2008-2019 examined. Further evidence is that the null hypothesis that the four time series (in the entire period 2008-2019) are normally distributed cannot be rejected, as illustrated in Figure A.2 (see the section "Additional statistical tests" in the Appendix).

Discussion

The analysis showed that the DF did not produced any significant increase in any of the four dimensions of interest. However, this result should be considered with prudence, in view of some significant limitations of this research:

- The analysis was based on a sample of 244 out of a total of 972 PoliTO tenured researchers, who represent 16 out of a total of about 40 disciplines.
- Three years (i.e., 2017-2019) is a relatively limited period to evaluate the (missing) effects of the DF, especially considering the intrinsic inertia associated with the production of scientific publications and the citation accumulation. However, the fact remains that in the Engineering field, the production of publications is relatively faster than in other fields, which makes the results of the analysis interesting, at least at a preliminary level (Moed, 2010b).
- The analysis dimensions are strictly focused on scientific publications, which implies neglecting other important scientific outputs for the life of a researcher, such as participation in (national/international) projects, teaching, or technology transfer activities. The reason for this "under-representation" is the difficulty of collecting objective and complete data on these other scientific outputs.

Returning to the DF, the author believe that it certainly gave the PoliTO researchers a certain sense of peace of mind, eliminating the hassle of increasing the indicators of research output, at least in the short term (Laudel, 2006). This is due not only to the amount of the funding but also to the rules that govern it:

- There are no time restrictions on the use of funds;
- There are no restrictions on the type of expenditure (e.g., distinguishing between "noble" expenditure, such as acquisition of research equipment or payment for research missions, and less noble expenditure, such as purchase of consumables, computer equipment, office furniture, etc.).
- There is no obligation for the researcher to co-finance the expenditure, which – according to some authors (Bolli and Somogyi, 2011) – would be an important deterrent for the purchase of material that is not strictly important for research.

- There are no minimum results for the receipt of new annual funds (i.e., 14k€ per year), depending on the research activity resulting from the use of the funds received in previous years.

The introduction of some constraints to these relatively "libertarian" rules could probably lead to more concrete results (Bolli and Somogyi, 2011). Nevertheless, it is not excluded that the initiative may be effective in the medium to long term, as it is. In this respect, we plan to investigate whether the results of this short-term study will be confirmed in the medium-long term, perhaps considering a larger sample of researchers from PoliTO and the OU.

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Appendix

Additional statistical tests

Table A.1 contains the results of an additional Kendall's Turning Point test for each of the four dimensions considered (Kendall, 1973; Brockwell and Davis, 2016). This other test is performed to check the randomness of the time series, using the totality of the data (i.e., from 2008 to 2019). For the first three time series, the null hypothesis of randomness cannot be rejected at a confidence level of 95% (p-values > 0.05); for the last one, randomness is doubtful (p-value = 0.013), due to the relatively high number of turning points; this result can somehow be affected by the relatively low number of data, therefore it should be considered with prudence (Ross, 2009).

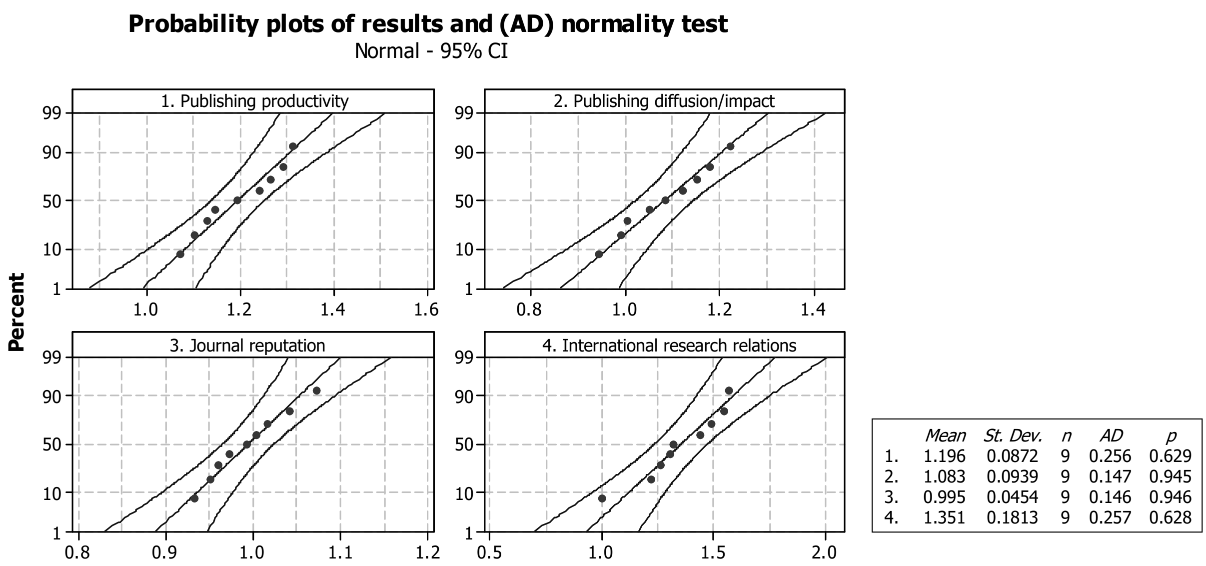
Table A.1. Results of Kendall's Turning Point test for testing the randomness of the four time series in Figure 2, considering the totality of the data (i.e., from 2008 to 2019).

Dimension	*maxima*	*minima*	T_p	n	z	p
(1) Publishing productivity	3	3	6	12	-0.495	0.620
(2) Publishing diffusion/impact	4	4	8	12	0.991	0.322
(3) Journal reputation	4	3	7	12	0.248	0.804
(4) International research relations	5	5	10	12	2.477	0.013

Note:

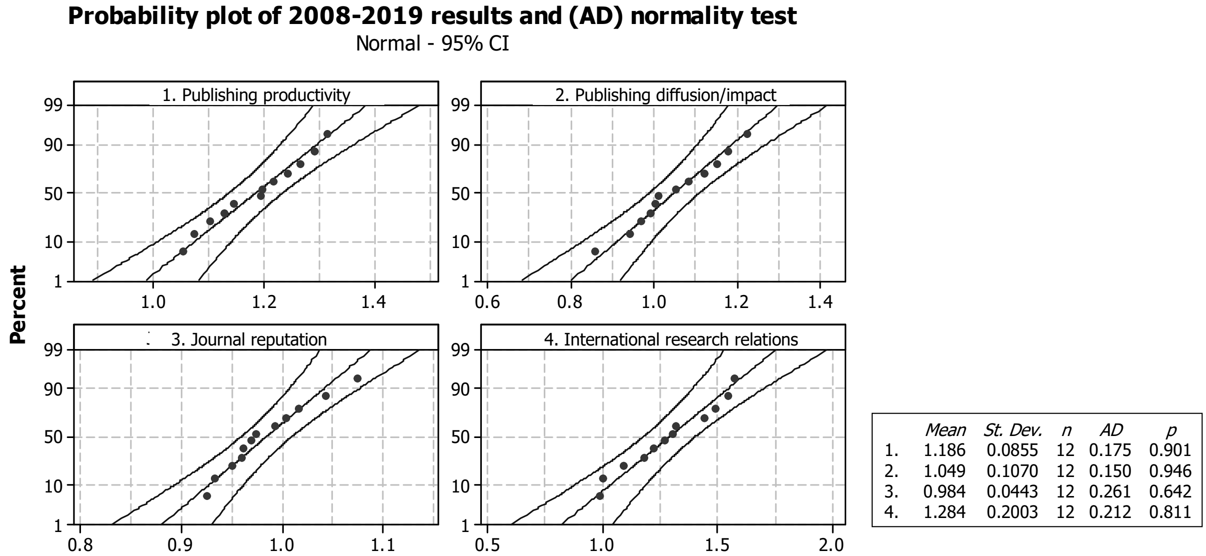
- The number of (local) *maxima*/*minima* are determined excluding the extremes of the time series.
- T_p is the number of so-called *turning points*, i.e., $T_p = maxima + minima$.
- $n = 12$ is the number of points taken into account for each time series (i.e., from 2008 to 2019).
- The test statistic is $z = \dfrac{T_p - \dfrac{2 \cdot n - 4}{3}}{\sqrt{\dfrac{16 \cdot n - 29}{90}}}$ (Kendall, 1973; Brockwell and Davis, 2016).
- The p-value of the two-tailed test is defined as $p = 2 \cdot [1 - \Phi(|z|)]$ (Kendall, 1973; Brockwell and Davis, 2016).

Figures A.1 and A.2 illustrate two Anderson Darling normality tests at 95%, for each of the four time series in Table 6, considering respectively (i) the 2008-2016 data (i.e., excluding the effects of DF), and (ii) the 2008-2019 data (i.e., including the effects of DF). The authors are aware that the power of these tests is not very high, due to the relatively limited number of data (i.e., 9 in the first case and 12 in the second one) (Ross, 2009). Nevertheless, it is interesting to note that for all the considered time series the null hypothesis of normal distribution cannot be rejected.



Note:
n is the number of data considered for each time series (i.e., 9 in this case, since the period 2008-2016 is considered).
AD is the so-called Anderson-Darling statistic.
p is the corresponding *p*-value.

Figure A.1. Results of the Anderson Darling normality test applied to the time series in Table 6 (data included in the period from 2008 to 2016).



Note:
n is the number of data considered for each time series (i.e., 12 in this case, since the period 2008-2019 is considered).
AD is the so-called Anderson-Darling statistic.
p is the corresponding *p*-value.

Figure A.2. Results of the Anderson Darling normality test applied to the time series in Table 6 in their totality (i.e., considering all of the annual data in the period from 2008 to 2019).