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Examining how country-level science policy shapes publication patterns: the case of Poland

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Abstract
This country case study describes how science policy instruments are designed to shape publication patterns and identifies the changes in researchers' productivity that can be observed over the period 2009–2016 in Poland by analysing data on 452,277 publications submitted to the country's national research evaluation system. Our analysis reveals that policy instruments used in the country's national research evaluation system, academic promotion procedures and competitive grants have increased the number of articles with an impact factor without compromising publication quality, as measured by a bibliometric indicator. Our findings highlight that only clear and stable incentives have influenced researchers' publications. Therefore, patterns in scholarly book publications—for which regulations were not clear and stable—have not been significantly shaped by science policy.

Keywords Science policy · Incentives · Poland · Research evaluation · Publication patterns

JEL Classification I23

Mathematics Subject Classification 00-02

Introduction

Policy makers implement numerous policy instruments to stimulate world-class science and education, and to foster innovation at the national level, yet the question of how such science policy instruments shape and actually affect the production of knowledge and the dissemination of research results still remains unanswered, despite the various theoretical frameworks and empirical studies that have been proposed and conducted (Butler 2005; Schneider et al. 2016; van den Besselaar et al. 2017). Further, some studies argue that a single cause for the growth in publications recorded in international databases cannot be

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traced (Jiménez-Contreras et al. 2003), with a variety of factors needing to be investigated further (Pajić 2015).

In this paper, we understand shaping the dissemination of research as shaping the publication patterns of a given researcher, institute or discipline. These patterns are described in the types of publications (e.g. articles, scholarly books, patents), collaboration patterns and other indicators relevant to scholarly publications. In the sciences, publication patterns are shaped through a variety of factors depending on the discipline (Engels et al. 2012), such as epistemic cultures (Knorr Cetina 1999), citation cultures (Wouters 1999) and the growing importance of interdisciplinary research and cooperation (Levitt and Thelwall 2016). These factors are integral to science and research, and substantially influence what type of publications are favoured, what publication language is most often used, how many authors prepare publications, and which journals in a given discipline are acknowledged by the academic community as a valid way of communicating research results.

Science policy serves to achieve a number of goals that are important to society, the economy or to science itself. One of the most commonly used instruments of science policy is research evaluation. *Ex post* evaluation is conducted at the levels of individual researchers, higher education institutions, disciplines or regions, whereas *ex ante* evaluation is most often used to assess research project proposals. In all types of evaluations, publications are the key indicator through which researcher productivity and excellence or the impact of the research are assessed (Aksnes et al. 2012; Kulczycki 2017). The aim of research evaluation is very often connected to science policy goals. One such goal is to improve the productivity of researchers, such as by increasing the number of publications with an international author. Research evaluation may also facilitate the distribution of funding across institutions in a given country.

In general, it can be agreed that the level of public R&D funding is the most important instrument in shaping research activities at the institutional (Henriksen and Schneider 2014) and individual levels (Franzoni et al. 2011). Other mechanisms, such as different models of university governance, competitive grants and promotion procedures, also influence publication patterns to some extent. The instruments which focus on the productivity of researchers can have both positive and negative consequences on research practices. For example, such instruments can increase the number of publications in top-tier channels but, at the same time, can push researchers into conducting some questionable practices (Aagaard and Schneider 2017; Bal 2017). Nonetheless, there are no easy answers to the question of how science policy actually shapes publication patterns, due mostly to the complexity of the research and the policies themselves.

Policy makers design incentives to support the transformation of publication patterns and researcher behaviours. The incentive to publish first and foremost in international journals became common in the 1980s. Incentives to publish can be direct, such as the monetary reward systems in Mexico (Neff 2017) and China (Quan et al. 2017); as per these systems, if a researcher publishes in a way promoted by an incentive, they can receive extra funding or a larger salary. Not only do direct cash incentives influence how researchers publish their results, but can also affect career incentives (e.g. tenure in the U.S. or various national academic promotion procedures in European countries), with the evaluation of proposals for competitive grants also influencing publication patterns (Franzoni et al. 2011).

There are also two other types of instruments that incentivise institutions to transform the publication patterns of their academic staff members. The first is the performance-based research funding system (PRFS), which is often combined with a country's research evaluation system at a national level (Hicks 2012; Kulczycki et al. 2017; Sivertsen 2016).

Such systems operate in the Czech Republic, Denmark, Finland, Norway, Poland and the United Kingdom. In these systems, bibliometric indicators serve to incentivise specific publication channels (e.g. journal articles have more weight than book chapters), languages, or by regulations on publication counting, cooperation across institutions and countries. Institutions are funded (fully or partially) on the basis of the results of research evaluation. Thus, changing publication patterns to improve the results and obtaining more funding has become one of the strategic goals of many institutions to bring direct funding to those institutions. The second instrument emphasises prestige distribution rather than financial incentives. Such an instrument can be observed in Australia where the national research evaluation framework (Excellence in Research for Australia) has shifted from a PRFS instrument to one that assesses the excellence and impact of the research. The results of this framework have no direct financial consequences.

Discussions on the effects of science policy on publication practices have focussed on a single discipline (Neff 2017), an institution (Hammarfelt and de Rijcke 2015), or countries (Aagaard 2015; Aagaard and Schneider 2017; Schneider et al. 2016). One of the first such studies showing the consequences of science policy on publication patterns at the national level was Butler (2003), analyzing Australia's increased proportion of publications indexed in the Science Citation Index and showing that even with an increase in publications in top-tier journals, citation impact declined. Some years later, van den Besselaar et al. (2017) extended Butler's analysis and then argued that the output-based research funding in Australia had a positive effect on research quality. Butler's response (2017) to the contradiction highlighted that van den Besselaar et al. (2017) was inaccurate and misrepresented several of Butler's (2003) original statements.

Neff (2017), in investigating the Mexican situation, showed that the system of monetary incentives had increased productivity (more publications in top-tier journals) but, at the same time, had undermined Mexico's ability to benefit from ecological research conducted by Mexican researchers. That study was criticised by Williams and Morrone (2018), who argued that the system has actually strengthened the quality of science at regional, national and international levels. Neff (2018) replied, stating that what the Mexican incentive system primarily does is unintentionally influence the research agenda of Mexican scholars.

So, in this paper, we aim to advance knowledge in regard to the effects of science policy on publication patterns, with specific respect to the Polish policy regimes. To this end, we reconstruct the goals and instruments of science policy in Poland and analyse the data from the Polish research evaluation system in the period 2009–2016 in all fields of science. We investigate how the country-level science policy shaped publications patterns over the last decade through PRFS incentives included. In our view, in the analysis of the long-term outcomes of the policies, it was not possible to investigate isolated factors and determine how they actually influenced the effects. Rather, we assume that understanding the historically determined social, economic and cultural contexts allows us to describe and detail the interacting network of factors that shaped the publication practices.

Science policy in Poland

The Polish case might be interesting for several reasons. First, Poland is one of the countries that underwent a democratic transition at the end of the previous century, and had to design an entirely new science policy. Secondly, for almost three decades Poland has used a performance-based funding system, which for over a decade implemented direct incentives regarding publication patterns. Finally, Poland is one of the biggest European countries that collects and uses full (not only indexed in the Web of Science [WoS] or Scopus) bibliographic information in their national research evaluation system. Thus, investigating what science policy instruments have been implemented and analysing changes in publication patterns may shed more light on how science policy shapes researcher publication practices.

Starting point and the context: democratic transition and teaching mission

After World War II, Poland entered the communist bloc. The aim of research then in all fields was to develop a socialistic economy and society. This aim was to be achieved through central planning of all research activities, topics and resources. The evaluation of the sciences was not perceived as a way to assess the quality of research, but rather as a tool to verify whether plans had been realised (Balazs et al. 1995).

The transition from this communist legacy to a democratic state influenced science funding and organisation from 1989 (Heinecke 2016, 2017; Jablecka 1995), after which the new socio-economic situation shaped new roles for higher education and science systems. On one hand, the higher education system evolved from an elite into an egalitarian system by, among others, strong privatisation of the system, which included boosting the 403,824 students in 1990 to 1,953,832 students in 2005 (Kwiek and Szadkowski 2018). On the other hand, research and science systems lost their important role in universities. The teaching orientation was predominant even at the top public research-intensive universities, especially within the social sciences and humanities (SSH) faculties. The massive expansion of higher education and the focus on the teaching mission made it so that 30–40% of the academics from the public sector (SSH) held parallel employment in the private sector during the expansion period (the peak was in 2005). Moreover, in the early 90 s, the economic crisis and the bankruptcy of many enterprises of the previous century broke down the many of the long-established industry-academia relationships.

As a consequence, universities abandoned their research mission from the 1990s to the mid-2000s, and Polish scholarly publications lost their international visibility (Kozak et al. 2014). In 1990, in the Polish higher education system there were 403,000 students and 112 institutions (11 universities), whereas in 2016 there were 1.35 million students and 390 institutions, of which 19 were universities (Główny Urząd Statystyczny 2017). The number of R&D personnel increased from 47,433 full-time equivalents in 1994 to 82,594 in 2015 in all sectors in Poland (Eurostat 2018).

Re-institutionalisation of the research mission: waves of reform since 2009

In 2008 the Ministry of Science and Higher Education presented the policy statements “Building on Knowledge” (2008a) and “Strategy for Development of Science in Poland until 2015” (2008b), which initiated large-scale reforms of the science and higher education sector. The reconfiguration of the system was intended to restore the research mission at Poland’s institutions of higher education (Kwiek 2014). The Ministry focused on four strategic goals: (1) raising the level and effectiveness of science in Poland and increasing its contribution in world science, (2) enhancing the use of science for national education and culture and raising the country’s civilisation level, (3) stimulating innovation in the Polish economy, and (4) achieving closer integration with the European Research Area.

Throughout the period 2009–2016 there have been various regulations and incentives to promote publishing in journals with an impact factor. The strategic goals of the Polish science policy have been translated into various instruments. Incentives for the first goal were expressed by (1) highlighting the importance of publications in the Journal Citation Reports within the national research evaluation system, academic promotion procedures and competitive grants; (2) assigning in the national evaluation more points to publications written in English than in other languages; and (3) limiting the number of publications that could be submitted to the national evaluation exercise, which motivated the scientific units to focus on collecting better publications (in terms of obtained points) rather than more publications. For the second goal, a special ministerial programme for funding projects in the humanities was established. The third goal was incentivised by emphasising publications in the JCR and not limiting the number of patents that could be submitted for assessment in the national evaluation. Finally, achieving the fourth goal was incentivised by focusing on publications in English and publications in the JCR within the national evaluation.

Three aspects of the 2009–2012 reforms were found to be actual game changers. The first such was establishing the Committee for Evaluation of Scientific Units (KEJN), which designs and conducts the evaluation of universities and research institutions. The second such was moving various mechanisms of funding from the state level to the intermediary level of the new agencies (Woźnicki 2013): the distribution of grant funding for basic and applied sciences was moved to the National Science Centre (NCN) and the National Centre for Research and Development (NCBR), respectively. The other game changer was introducing updated rules of academic promotions, especially for obtaining a habilitation degree (the scientific degree obtained after a PhD), which included an official list of scientometric criteria.

Institutional evaluation and its publication-oriented instruments

Evaluation in Poland is conducted at the level of a 'scientific unit,' such as an institution of higher education, a unit within an institution of higher education (e.g. a faculty), a research institute, or an institute of the Polish Academy of Sciences. Each institution submits publications of its academic staff member, and for each submitted publication (an evaluation item), the given scientific unit obtains a specified number of points. The number of points depends on various factors, including the type of publication channels, publication language and the number of authors. During the last three cycles of evaluation, the range of points assigned to the same publication types was changed several times.

Apart from publications, data concerning several other parameters were gathered for the purposes of the evaluation exercise (Kulczycki et al. 2017). These parameters were aggregated into four main criteria, which were later weighted and summed. As a result, the position of a scientific unit was determined among similar units in terms of scientific discipline. Based on the position of the unit in the ranking, a scientific category (A+, A, B or C) was assigned by the Ministry. Ultimately, the scientific category translated into the size a block grant from the Ministry. The block grants in case of units from universities is about 10% of their annual budget, while for basic and applied research institutes it is up to 30% of their annual budget.

Table 1 presents a comparison of science policy instruments related to publication patterns implemented in the regulations over the last three evaluation cycles. We focus on bibliometric indicators, publication counts, and patents.

Table 1 Science policy instruments implemented in the regulation of evaluation cycles in 2010, 2013 and 2017

Science policy instrument	The 2010 evaluation	The 2013 evaluation	The 2017 evaluation
Limited number of publications submitted by a scientific unit	$3N$, where N is the annual arithmetic mean of the FTE of academic staff members during the evaluated period	$3N-2N_0$, where N is the annual arithmetic mean of the FTE of academic staff members during the evaluated period, and N_0 is the FTE of academic staff members not publishing during the evaluated period	
Authors of publications	All publications must be authored and affiliated by at least one academic staff member of a given scientific unit	At least 80% of publications ($3N-2N_0$) must be authored by at least one academic staff member of a given scientific unit. All publications must be affiliated with the scientific unit	
Definition of scholarly book publications	Monographs/chapters/academic handbooks in English or in a fundamental language for a discipline (e.g. Czech for Czech philology) Monographs/chapters/academic handbooks in Polish or other languages The monograph length should be at least six author sheets[a] The chapter length should be at least one author sheet	The monograph length should be at least six author sheets. The chapter length should be at least half of an author sheet Handbooks are not recognised as monographs Monographs are divided into two categories: monographs in a fundamental language for a discipline or in the congress languages (i.e. English, German, French, Spanish, Russian, Italian)	The monograph length should be at least six author sheets. The chapter length should be at least half of an author sheet Two new subtypes of monographs were added: 1. Monograph with at least four authors. Their contribution (chapters) is marked. All authors are affiliated with the same scientific unit that submits the monograph for evaluation 2. Monograph with at least four authors. The contribution (chapters) is marked. All authors are affiliated with the same scientific unit that submits the monograph for evaluation. The contribution length is at least six author sheets
Limited number of scholarly book publications	The number of scholarly book publications cannot exceed $1.5N$	The number of scholarly books publications cannot exceed: 40% of publications ($3N-2N_0$) in the humanities and social sciences, ($3N-2N_0$)/3 of publications in the arts, 10% of publications ($3N-2N_0$) in other fields	The number of scholarly books publications cannot exceed: 40% of publications ($3N-2N_0$) in the humanities and social sciences, 25% of publications ($3N-2N_0$) in the arts, 20% of publications ($3N-2N_0$) in engineering, 10% of publication ($3N-2N_0$) in life sciences

Table 1 (continued)

Science policy instrument	The 2010 evaluation	The 2013 evaluation	The 2017 evaluation
Editorial roles	Editing monographs, handbooks or series by academic staff members of a given unit Editing scientific journal indexed in the Journal Citation Reports (JCR) or the European Reference Index for the Humanities (ERIH)	Editing monographs by academic staff members of a given unit Editing scientific journal indexed in the Journal Citation Reports or, only for the humanities and social sciences fields, editing scientific journal indexed in the European Reference Index for the Humanities	Editing monographs by academic staff members of a given unit Editing scientific journal indexed in the Journal Citation Reports
Journal articles	Articles from journals indexed in the JCR Articles from journals indexed in the ERIH Articles in other journals indexed in the Polish Journal Ranking Articles in other journals not indexed in the Polish Journal Ranking	*A list* Articles from journals indexed in the JCR *B list* Articles from journals assessed according to the Polish Journal Ranking regulations not indexed in either the JCR or ERIH *C list* Articles from journals indexed in the ERIH Articles in other foreign journals in the congress languages	*A list* Articles from journals indexed in the JCR *B list* Articles from journals assessed according to the Polish Journal Ranking regulations not indexed in either the JCR or ERIH *C list* Articles from journals indexed in the ERIH Articles in other foreign journals (all languages except Polish)
Citations	The number of citations of a given scientific unit from the previous year on the basis of the WoS (or Google Scholar)	Citations are calculated on the basis of the WoS and only for the scientific units that can obtain the highest results (the A + category)	No citation analysis

Table 1 (continued)

Science policy instrument	The 2010 evaluation	The 2013 evaluation	The 2017 evaluation
Publication counting	Points are divided according to the number of authors: Up to 10 authors: 100% of points More than 10 authors: 100% of points when at least 50% but not less than 10% of authors are affiliated with the given scientific unit More than 10 authors: 25% of points when less than 10% of authors are affiliated with the given scientific unit	Points are divided according to the number of authors: Up to 10 authors: 100% of points More than 10 authors: 100% of points when at least 20% of authors are affiliated with the given scientific unit More than 10 authors: 75% of points when at least 10% of authors are affiliated with the given scientific unit More than 10 authors: 50% of points when less than 10% of authors are affiliated with the given scientific unit	
Patents	Patents are counted separately from publications within the practical applications criterion within the $2N/3N$ limit National and international patents are counted together with patent applications	Patents are counted together with publications within the $3N-2N_0$ limit National and international patents are counted Patent applications are not counted	Patents are counted together with publications The number of submitted patents is not restricted National and international patents are counted Patent applications are not counted

FTE full-time equivalent

[a] 1 author sheet = 40,000 characters or approximately 6000 words

Other national instruments focused on publication patterns

Via the 2009–2012 reforms, two other instruments were implemented:

1. Mechanisms of the NCN in Poland:
    a. Since the very first call for proposals in March 2011, researchers presenting their research portfolio are obliged to provide the values of their h-indexes and the total number of citations: researchers from the hard sciences must use the WoS Core Collection, whereas researchers from the soft sciences must use either WoS or Scopus (they can also use other sources, such as Google Scholar).
    b. Researchers must provide bibliographic information for up to 10 publications from the last 10 years with the number of citations (without self-citations) for each publication. Where it is possible, a 5-year journal impact factor for journals must be provided.

In the era before the NCN, grant proposals were submitted to the State Committee for Scientific Researchers and later to the Ministry of Science and Higher Education, which officially did not use any bibliometric indicators for the required bibliographic records of publications (Antonowicz et al. 2017).

2. Assessment criteria in the habilitation procedure:
    a. In September 2011, the Ministry of Science and Higher Education established for the very first time detailed criteria of assessment for candidates for a habilitation degree. The old rules ran parallel to the new one (i.e. established in September 2011) until September 2013.
    b. Candidates from the humanities and the arts must list their publications that are indexed in the WoS or the ERIH. For candidates from social sciences, these publications must be listed in the JCR or the ERIH. For candidates from the hard sciences, these publications must be listed in the JCR. Additionally, candidates must present the values of three bibliometric indicators on the basis of the WoS: citations, h-index and the Total Impact Factor [whose formula is similar to the 'total impact' (Beck and Gáspár 1991) and the 'author impact factor' (Pan and Fortunato 2014)].

Data and methods

Dataset

A complete data set from the previous two cycles of evaluation was used in our analysis. During the evaluations, all scientific institutions submitted a questionnaire along with bibliographical records of publications and patents affiliated with those units for the periods 2009–2012 and 2013–2016. Each bibliographical record or patent submitted by an institution is called an *evaluation item*. From the perspective of a given institution, an evaluation item always refers to a 'publication', therefore in presenting our results, we use the term 'publications'.

In Poland, an adaptation of whole counting of publications was used (Kulczycki 2017). A publication authored by three scholars from three different Polish scientific units was submitted separately by each of those units. Thus, in the final dataset, there were three *evaluation items* (bibliographical records) for one publication. All data concerning publications are aggregated in the same way as in the evaluation, that is, using the whole counting method.

For the 2009–2012 period, scientific units submitted 532,343 evaluation items related to publications and 4503 items related to patents, while for the 2013–2016 period they submitted 581,106 and 5932 items, respectively. The full-time equivalent of academic staff members in the first period was 82,867.09 and in the second period 86,461.84.

As discussed in the previous section, the evaluation assessed a limited number of *evaluation items* related to publications; i.e. $3N-2N_0$, where N is the annual arithmetic mean of the full-time equivalent (FTE) of academic staff members who worked in a scientific unit during the evaluated period, and N_0 is the FTE of academic staff members not publishing during the evaluated period. The result of the $3N-2N_0$ formula presents the number of *slots* that can be filled by *evaluation items*. One evaluation item (i.e. publication) can take one slot, three-quarters of a slot or half a slot depending on the number of authors from the submitting institutions (see Table 1 for further details). The number of assigned points to a publication is multiplied by the amount of slot space taken.

In our analysis, therefore, we use the evaluation items that meet the following criteria: (1) were affiliated with researchers who were academic members of scientific institutions to which they affiliated publication; (2) were accepted by the experts, meaning that the publications met all the criteria (e.g. a monograph's length is at least six author sheets); and (3) the filled *slots* were calculated by the $3N-2N_0$ formula. All exceptions from these rules are clearly marked.

For the analysis, the following variables were used:

- Five nominal variables: (1) *language* (all original values were re-coded to English, Polish and other languages); (2) *publication type* (journal article, monograph, edited volume, book chapter); (3) *article journal type* (A list, other); (4) *field* (Natural Sciences, Engineering and Technology, Medical and Health Sciences, Agricultural Sciences, Social Sciences, Humanities); and (5) *patent type* (national, international).
- Four numeric variables: the *number of authors from a scientific unit, the number of authors not from a scientific unit, the total number of authors,* and the *publication length*.
- Two rank variables: (1) *year* (2009–2016) and (2) *journal quartile according to the 5year impact factor.*

In this study, we present yearly data only on journal articles from the *A list* and monographs. Due to the limited number of publications and range of points, other publications types (i.e. chapter, articles from the *B* and *C lists* journals and edited volumes) were *pushed out* of the final set of evaluation items. On the contrary, the *A list* articles and monographs were assigned a substantially higher number of points; thus, there was no *push out* effect. This means that in the final number of publications (more precisely, evaluation items related to publications) calculated on the basis of the $3N-2N_0$, there is a substantially lower number of publications in local journals or book chapters. This is why we did not analyse other publication type except the *A list* articles and monograph because the scale point would bias the results.

We used five-year impact factor values from a given year and rankings designed within the subject categories and not the *points* to avoid biases caused by changes in the range of points assigned to the *A list*. Based on this information, we calculated in which quartile a given journal within a subject category was classified in every year. If a journal was classified in more than one subject category, we chose the maximum value (i.e. the highest quartile). This operation allowed us to investigate whether the quality of articles affiliated with Polish scientific institutions (measured by the impact factor values) had been changing over the analysed period.

Mapping evaluation items to the OECD fields

In Poland, evaluation is conducted at the level of scientific units. In this way, all publications and patents are classified to fields according to the organisational classification (Daraio and Glänzel 2016).

Each scientific unit was assigned to one of the 60 Joint Evaluation Groups in the 2013 evaluation and 67 Joint Evaluation Groups in the 2017 evaluation. For instance, all faculties of history were assigned to a single Joint Evaluation Group for the units from higher education institutions, and institutes of the Polish Academy of Sciences from the social sciences and humanities group were assigned to their single Joint Evaluation Group.

For the purpose of the analysis, we manually assigned each of the 1000 + scientific units according to their Joint Evaluation Group and type of science to one of the six Fields of Science and Technology of the OECD fields.[1] All scientific units from the group of art sciences and artistic production were excluded from the final dataset because in the overwhelming majority they submitted artworks and not publications to the evaluation. All the publications and patents of a given scientific unit were assigned to one OECD field.

Publication types

All publications in both the 2013 and 2017 evaluations were classified into one of four publication types: journal article, monograph, edited volumes and book chapters.

Publications were translated into points a given unit could obtain (Kulczycki et al. 2017). The average of points per FTE (not only obtained via publications but also via other R&D activities) served to assign the scientific category (A+, A, B, C) for the unit, which expressed the quality of outcome and activities of a given scientific unit. Scientific categories are used as an indicator in the formula for annual distribution of government block grants to scientific units.

Journal articles were assessed according to the Polish Journal Rankings (Kulczycki and Rozkosz 2017) published in 2009, 2010, 2012, 2013, 2015 and 2016 by the Ministry of Science and Higher Education in Poland. Each ranking consists of three lists: A, B and C. The number of points assigned to a journal depended on the following:

- *A list* (15–50 points): journals with a five-year impact factor (or two-year impact factor if the five-year impact factor was not available). The number of points was normalised using the WoS subject categories.

[1] OECD: revised field of science and technology (FOS) classification in the Frascati manual, version 26-Feb-2007, DSTI/EAS/STP/NESTI (2006)19/Final.

- *B list* (1–15 points): journals not indexed in the Journal Citation Reports were assessed according to various formal (e.g. the share of authors from foreign institutions) and bibliometric (e.g. the predicted impact factor) criteria.
- *C list* (10–25 points): journals indexed in the European Reference Index for Humanities. The number of points depended on the journal category within the index.

During the 2009–2016 period, numerous changes to the Polish Journal Ranking regulations were implemented, especially for the *B list*. The most significant changes concerned the range of points assigned to journals indexed in the 2009–2012 period (a normalisation was not conducted): articles from 2009 had a substantially lower number of points in relation to articles published in the same journals after 2009. This change, in combination with the $3N-2N_0$ formula, provided an unusually large number of publications in the *B list* from 2010 in relation to publications from 2009 and 2011–2012 in the final dataset used in the evaluation.

Monographs (20 or 25 points according to the publication language), edited volumes (4 or 5 points according to the chapter language) and book chapters (4 or 5 points according to the chapter language) were assessed according to various formal and technical criteria presented in Table 1. The $3N-2N_0$ formula and a low number of points assigned to book chapters also provided in the final dataset a share of book chapters substantially lower than when we took into account all the publications that were not limited by any formula (Kulczycki et al. 2018).

Results

Characteristics of the publications included in the $3N-2N_0$ limit

Table 2 shows the distribution of publication types in the period 2009–2016. For the analysed period 452,277 publications were submitted for the two evaluation exercises. The highest number of researchers (more precisely, FTE of academic staff members) were from Engineering and Technology (22,195), and the lowest number of researchers from Agricultural Sciences (7326). In the so-called hard sciences, the highest share was constituted by journal articles from the *A list* (from 38.3% in Engineering and Technology to 88.4% in Natural Sciences), whereas in Social Sciences and Humanities this share was 7.1% and 2.4%, respectively. Journal articles from the *B list* played a major role in Social Sciences. Monographs were prevalent in Social Sciences and Humanities. However, in none of the fields was the share close to the limit (e.g. only 23.1% of monographs in Humanities, where the limit was 40%). Patents were submitted in all fields except for Humanities. The highest number of patents was submitted in Engineering and Technology (7010 patents), the lowest number of patents was submitted in Social Sciences (48 patents), and no patents were submitted in Humanities. In Table 2, we present all submitted patents except those rejected by the evaluators.

Publication patterns: articles in journals indexed in the Journal Citation Reports

Table 3 shows the distribution of journal articles published in the *A list* journals (indexed in the JCR) per quartile (calculated according to the procedure described in Sect. 3.1) in the period 2009–2016. The total number of publications submitted by all scientific units

Table 2 Numbers and percentages of publications submitted for the evaluation exercise within the $3N-2N_0$ limit per type in the period 2009–2016

Fields	N_e	N_0	A list article N (column %)	B list articles N (column %)	C list article N (column %)	Other articles N (column %)	Monograph N (column %)	Chapter N (column %)	Edited volume N (column %)	Total number of publications (N)	Patents[a] (N)
Natural Sciences	13,081.69	442.67	69,095 (88.4)	5355 (6.9)	123 (0.2)	1041 (1.3)	1593 (2.0)	666 (0.9)	267 (0.3)	78,140	2283
Engineering and Technology	22,195.11	881.84	42,805 (38.3)	40,660 (36.4)	108 (0.1)	12,612 (11.3)	5551 (5.0)	9098 (8.2)	865 (0.8)	111,699	7010
Medical and Health Sciences	13,392.09	509.73	55,485 (71.4)	18,504 (23.8)	206 (0.3)	706 (0.9)	1559 (2.0)	539 (0.7)	666 (0.9)	77,665	631
Agricultural Sciences	7326.00	126.24	26,131 (62.1)	13,260 (31.5)	21 (0.1)	487 (1.2)	1573 (3.7)	453 (1.1)	179 (0.4)	42,104	1281
Social Sciences	16,204.93	740.49	6654 (7.1)	53,920 (57.4)	4343 (4.6)	2303 (2.5)	15,452 (16.5)	6301 (6.7)	4928 (5.3)	93,901	48
Humanities	9097.26	380.46	1159 (2.4)	18,845 (38.6)	11,298 (23.2)	225 (0.5)	11,272 (23.1)	2404 (4.9)	3565 (7.3)	48,768	0
Total	81,297.06	3081.41	201,329 (44.5)	150,544 (33.3)	16,099 (3.6)	17,374 (3.8)	37,000 (8.2)	19,461 (4.3)	10,470 (2.3)	452,277	11,253

[a] All submitted patents not rejected by the evaluators

N_e—arithmetic mean of the number of academic staff members who worked in all scientific units during the evaluated period in a field; N_0—number of academic staff members not publishing during the evaluated period

Table 3 The number of publications from the *A list* per type quartile in the period 2009–2016

Publications limited to $3N-2N_0$						Total number of publications submitted without rejection	Number of Polish contributing authors	% not included in $3N-2N_0$
Year	Q1	Q2	Q3	Q4	Total number of publications			
2009	4930	3662	3239	2956	14,787	15,624	20,261	5.4
2010	6609	4850	3671	3946	19,076	20,351	24,711	6.3
2011	7064	5203	4451	5330	22,048	23,824	29,884	7.5
2012	8341	5813	5143	5867	25,164	27,538	33,467	8.6
2013	8966	6507	3853	5062	24,388	31,886	25,666	23.5
2014	10,178	6939	5532	5259	27,908	35,457	28,810	21.3
2015	11,652	8625	5894	5717	31,888	39,652	31,963	19.6
2016	13,363	9521	6130	6144	35,158	42,826	34,508	17.9
Total	71,103	51,120	37,913	40,281	200,417	237,158	–	15.5

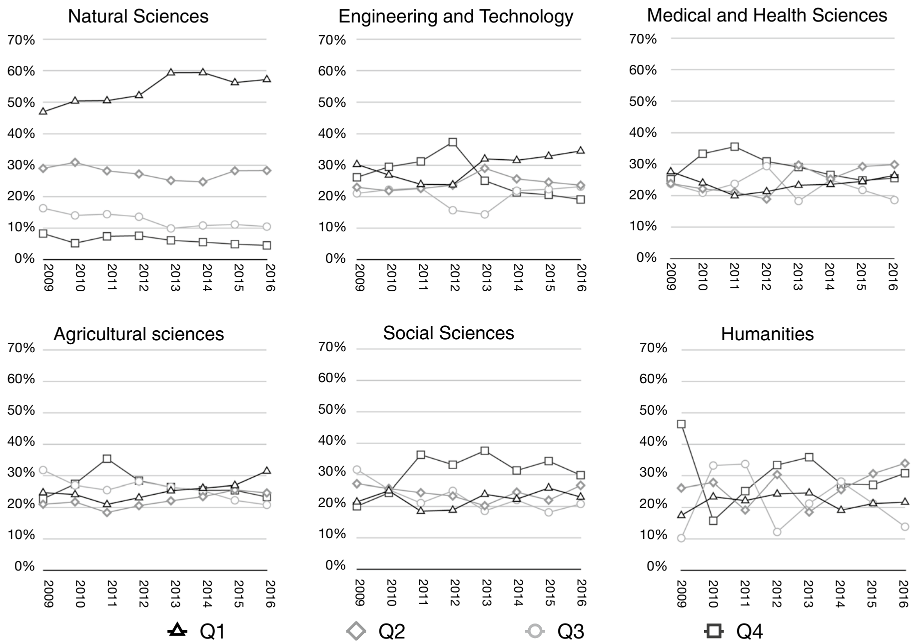

Fig. 1 The share of publications submitted for evaluation within the $3N-2N_0$ limit in quartiles across the OECD fields in the period 2009–2016

was 237,158, of which 84.5% (200,417 publications) was included in the final number of publications limited by the $3N-2N_0$ formula. A significant growth in the number of publications classified was observed; for example, there was an increase from 4930 publications in Q1 in 2009 to 13,363 publications in Q1 in 2016. In total, the number of publications multiplied in each quartile: the number of publications in Q1 rose to 2.7 times between 2009 and 2016, to 2.6 in Q2, to 1.9 in Q3 and to 2.1 in Q4.

Because of the points scale, if a unit has a large number of publications from the *A list*, only publications with the highest number of assigned points fall within the $3N-2N_0$ limit. The overall number of publications in the *A list* increased over the analyzed period, and as a consequence, some with the lowest number of points were not taken into account in the evaluation. Over the analyzed the eight-year period the number of researchers who were an author or co-author of at least one publication during a year had grown 70% from 20,261 to 34,508.

Figure 1 displays the share of publications limited by the $3N-2N_0$ formula from the *A list* per type quartile across the OECD fields in the period 2009–2016. In all fields, the publication patterns were stable. Nonetheless, there was a small growth in the share of publications in Q1. The highest share of publications in Q1 was in Natural Sciences, and the lowest share was in Humanities.

Figure 2 shows the number of academic staff members publishing in the *A list* journals across the OECD fields in the period 2009–2016. There are two numbers in each field: the number of academic staff members whose publications were submitted and not rejected, and the number of academic staff members whose publications were included within the $3N-2N_0$ formula limit. In total, the number of academic staff members (whose publications from the *A list* journals were submitted and not rejected) rose in each field. The

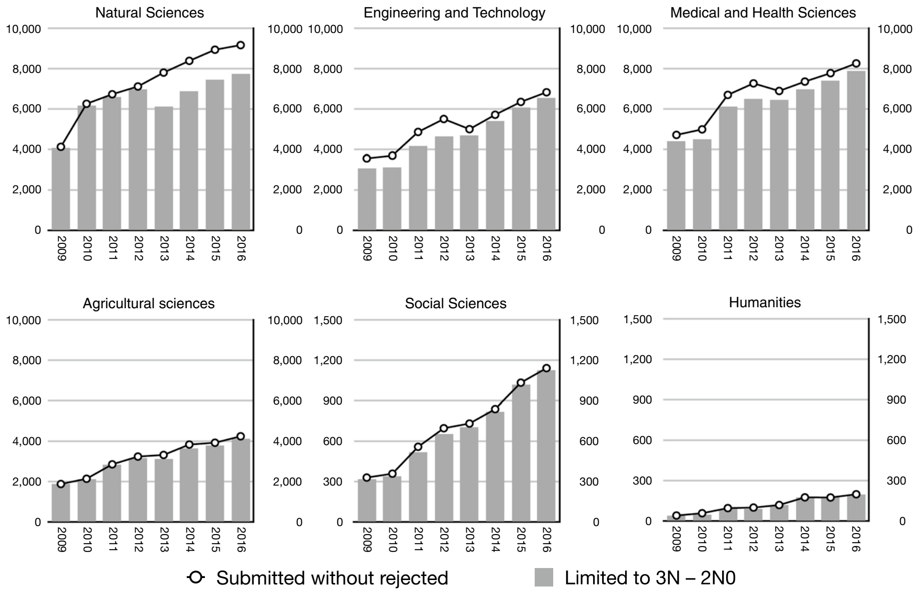

Fig. 2 The number of academic staff members publishing in the *A list* journals across the OECD fields in the period 2009–2016. The maximum scale of the vertical axis for both Social Sciences and Humanities is 1500, and 10,000 for the four other fields

number of academic staff members in Natural Sciences rose by 2.2 times between 2009 and 2016, by 1.9 in Engineering and Technology, by 1.8 in Medical and Health Sciences, by 2.3 in Agricultural Sciences, by 3.5 in Social Sciences and by 5.1 in Humanities. Natural Sciences had the largest number of publications not included in the $3N-2N_0$ limit, meaning that there were more articles than slots for publications which could be included in the $3N-2N_0$ limit.

Figure 3 displays the number of authors of *A list* articles. Three values for each field are presented: the mean number of authors from a scientific unit, the mean number of authors not from that scientific unit and the total number of authors. In all groups of sciences except Social Sciences, the number of external authors rose as a result of an increase in scientific cooperation. The results in Natural Sciences and Engineering and Technology were disrupted by publications from high-energy physics, in which publications with thousands of authors are quite common.

Publication patterns: monographs

Figure 4 shows the median length of monographs across the OECD fields. In the Polish system, an author sheet is used as a unit of analysis: one author sheet is 40,000 characters (approximately 6000 words). We used the median instead of the mean length because there were outliers caused by the small number of dictionaries, encyclopaedias and handbooks (especially in Medical and Health Sciences) which had a few standalone volumes, but were counted as a single publication with an excessive number of author sheets. As the length of the monograph was the key criterion of the scholarly

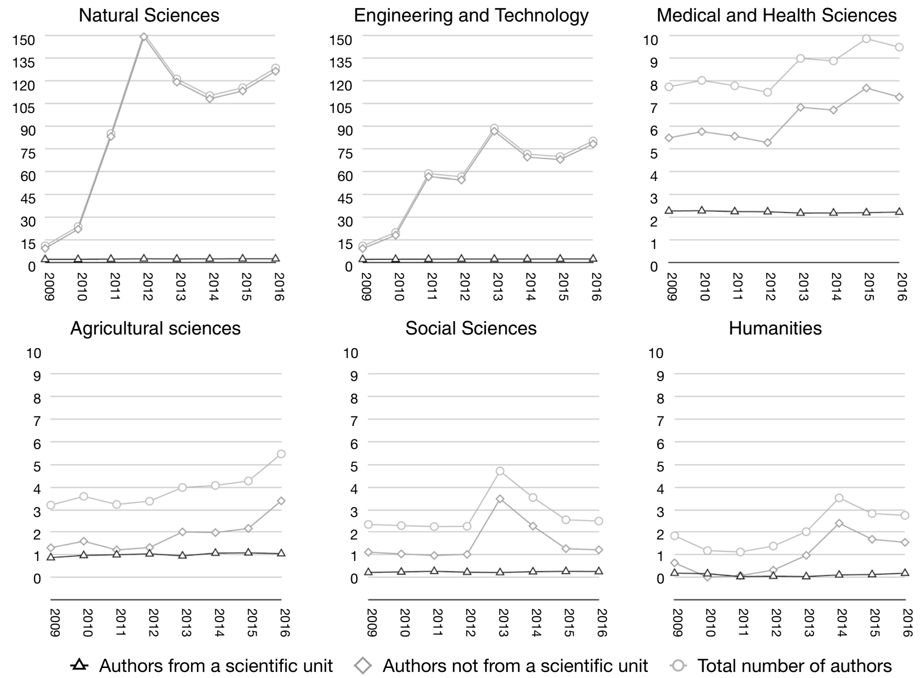

Fig. 3 The mean number of authors of *A list* articles submitted for evaluation within the $3N-2N_0$ limit across the OECD fields. The maximum scale of the vertical axis for Natural Sciences and Engineering and Technology is 150, and 10 for the four other fields

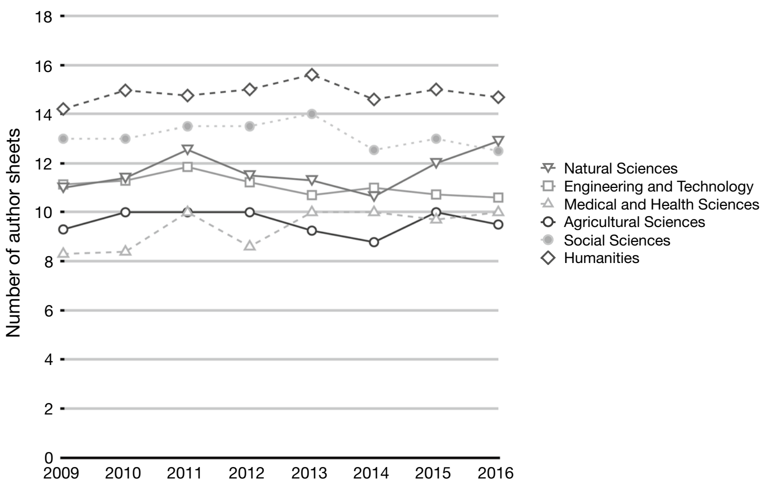

Fig. 4 The median length of monographs submitted for evaluation within the $3N-2N_0$ limit across the OECD fields

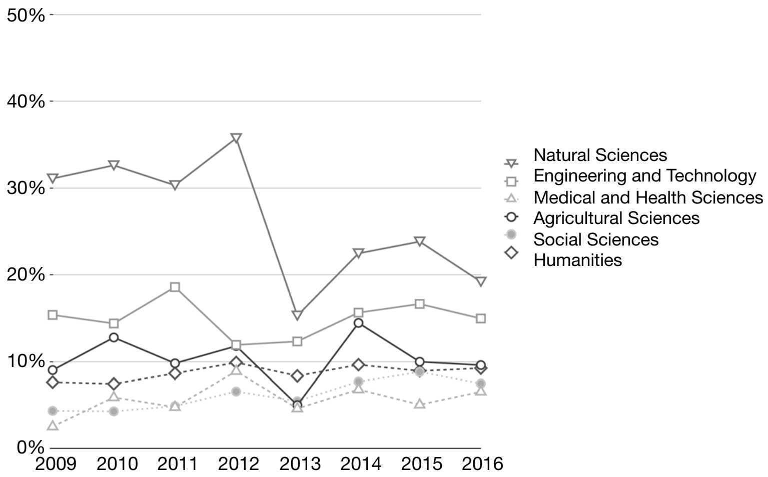

Fig. 5 The share of monographs submitted for evaluation within the $3N-2N_0$ limit in English across OECD fields

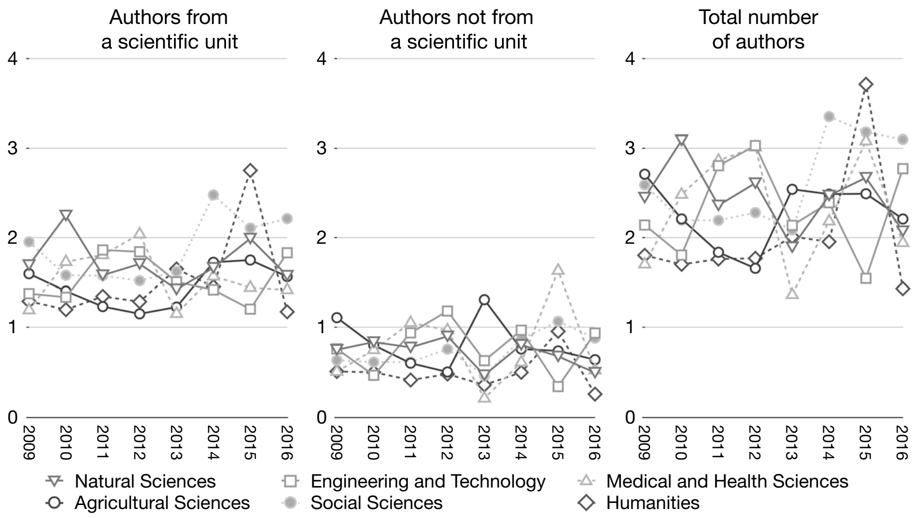

Fig. 6 The mean number of authors of monographs submitted for evaluation within the $3N-2N_0$ limit across the OECD fields

book evaluation, and there were no other quantitative criteria, the changes in monograph length could show that science policy influences publication patterns.

In all fields the median length was stable and no substantial variances were observed, despite changes in the definition of monographs from three to six author sheets as a counted type of publication in the evaluation. In almost all years in all fields, the mean length of monographs was between 8 and 16 author sheets. Humanities had the highest median, while Medical and Health Sciences and Agricultural Sciences had the lowest median.

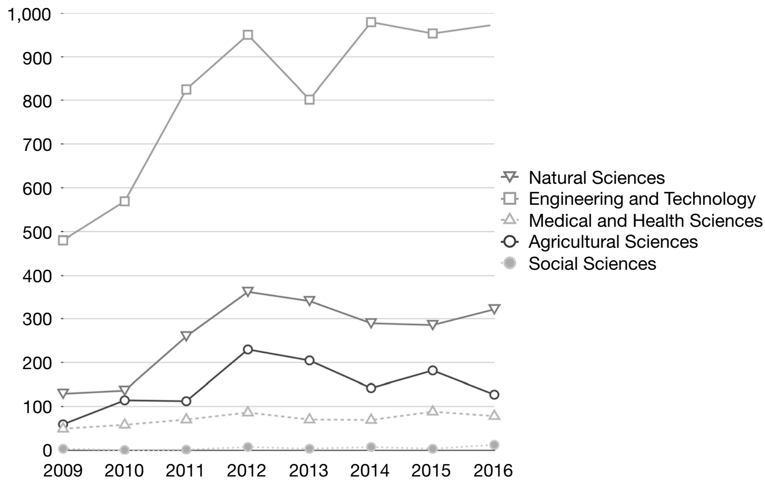

Fig. 7 The number of all patents submitted for evaluation across the OECD fields in the period 2009–2016

Table 4 The number of publications submitted to the PBN and to the 2017 evaluation for the period 2013–2016

Year	All publications			*A list* articles			Monographs		
	PBN	Submitted	$3N-2N_0$	PBN	Submitted	$3N-2N_0$	PBN	Submitted	$3N-2N_0$
2013	192,863	134,537	54,266	35,522	34,928	25,098	14,368	9000	6089
2014	206,468	141,145	58,003	38,598	37,979	28,707	13,677	7750	4496
2015	207,383	145,751	62,600	42,321	41,606	32,353	14,029	8206	4707
2016	199,092	143,728	66,096	45,078	45,135	35,562	13,183	8389	5165
Total	805,806	565,161	240,965	161,519	159,648	121,720	55,257	33,345	20,457

PBN—Polish Scholarly Bibliography; submitted—publications submitted to the 2017 evaluation; $3N-2N_0$—publications from the 2017 evaluation limited by the results of the $3N-2N_0$ formula

Figure 5 displays the share of monographs written in English. Overall, in the 2009–2016 period, 86.3% of monographs were written in Polish, 9.3% were written in English, 3.4% were written in congress languages (other than English), and 1.1% were written in other languages. The share of monographs in English was rather stable in all fields except Natural Sciences, in which there was a substantial drop in 2013.

Figure 6 presents the mean number of authors across the OECD fields. In the whole period the mean number of authors was stable.

Patents

Figure 7 shows the number of patents submitted across the OECD fields in the period 2009–2016. In this comparison we used all submitted patents that were not rejected by the evaluators (i.e. not limited by the $3N-2N_0$ formula). Humanities had no patents submitted in this field. Until 2012, there was substantial growth in the number of obtained patents. From 2013 the number of obtained patents stabilised, with a small decline in Agricultural Sciences.

The share of actual publication output we see in the evaluation

Since 2013, information about all publications by Polish scholars has been gathered in a national-level database: the Polish Scholarly Bibliography (PBN). Scientific units are responsible for the quality of data submitted to the PBN. A data quality check was only performed by KEJN for publications included within the $3N-2N_0$ limit. Table 4 displays the number of publications produced by Polish researchers in the period 2013–2016. We assume that, ideally, the PBN covered the total volume of publications from all fields in Poland.

From all the scientific units, 805,806 publications were submitted in the 2013-16 period, of which 565,161 (70.1%) were submitted for evaluation and 240,965 (29.9%) were included in the final number of publications limited by the $3N-2N_0$ formula. A total of 161,519 of the *A list* articles were submitted to the PBN by all the scientific units. Moreover, 159,648 (98.8%) of the *A list* articles were submitted to the 2017 evaluation and 121,720 publications (75.4%) were included in the final number of publications. There were 55,257 monographs, of which 33,345 (60.4%) were submitted to the evaluation and 20,457 (37.0%) were included in the final number of publications.

Discussion

Rijcke et al. (2016) show that the indicators affect the behaviour of institutions and individual scientists. The objectives of a scientific policy must be translated into a system of consistent indicators used throughout a system. Such a translation is needed in order to ensure that institutions and scientists in their daily work should not feel that what they must report is different or even incompatible from what must be delivered. On the basis of the conducted analysis, it can be concluded that in the scope of enhancing the effectiveness of Polish science, Poland has managed to build a coherent system consisting of a research evaluation system, academic promotion procedures and grant agencies.

Our findings show that the regulations of the Polish Journal Ranking for journals with an impact factor are working well. Namely, the number of publications indexed in the JCR has been growing steadily, and there is still potential to maintain this growth for another two or three evaluation periods. It is noteworthy that although the shares of publications in the JCR according to the quartiles were stable from 2009 to 2016, the number of publications from the JCR submitted for evaluation multiplied almost three times (from 15,624 in 2009 to 42,826 in 2016). This means that Polish researchers were able to increase productivity without decreasing the quality of their publications (in terms of the JCR quartiles).

We believe that the Polish model can be improved by implementing a non-linear scale that promotes publications in journals in higher quartiles (e.g. the current 15–50-point scale could be changed to a 10–100-point scale, for example). A new scale could prepare the Polish model for greater saturation with JCR publications. At present this can be observed in Natural Sciences, in which year by year, more and more publications from Q3 and Q4 have been pushed out by the $3N-2N_0$ limit.

Moreover, the growth in researchers publishing in the JCR journals may be acknowledged as a desired outcome of the Polish science policy. This means that the publication output in the JCR journals had increased not only by a small group of researchers who publish more each year, but also by other researchers who b to publish in top-tier journals.

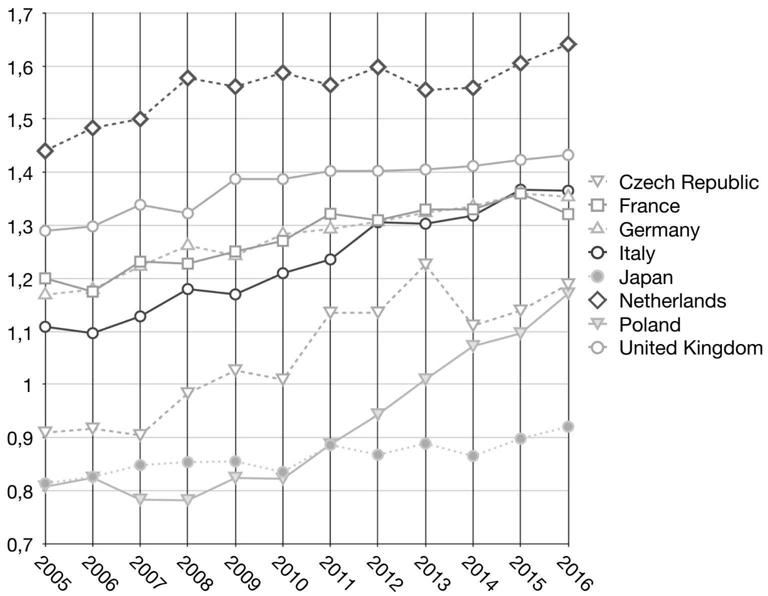

Fig. 8 The Category Normalised Citation Impact in the period 2005–2016 for all publication types. (*Source*: InCites Dataset)

If we assume that this trend continues, then good patterns and practices could also spread to other fields that are not as research-intensive (e.g. Social Sciences).

The PBN shows that the productivity of Polish researchers is stable; in other words, a similar number of papers are published each year. Nonetheless, the $3N-2N_0$ formula has produced a bigger share in the total volume constituted by publications in desired (from the science policy perspective) publication channels.

The effectiveness of Polish science is also visible in the WoS Core Collection: InCites Dataset (see Fig. 8). The Category Normalised Citation Impact before 2009 was relatively stable between 0.78 and 0.82. Later it had risen to 1.17 in 2016. This demonstrates that the *A list* with a scale from 15 to 50 points fulfils its role, i.e. it encourages publishing in the JCR journals. The results of Polish researchers are being progressively more cited and are becoming increasingly visible in the world.

The whole counting method for multi-authored publications used in Poland encourages collaboration with external research units, both national and foreign. This counting method allocates the full number of points regardless of the contribution from a given unit. It was very profitable to enter research collaboration with external partners, especially for units with not such a strong publication register because it was a win–win situation. All of the participating units did not lose anything from the evaluation exercise point of view.

During the 2009–2016 period, the monograph patterns were also stable. A few times the policy makers changed the minimum length of monographs (from three author sheets to six authors sheets). In the policy document there is no information regarding why such a criterion was implemented. As our results show, however, in the whole period, the mean number of sheets was at least two times higher than required in all the OECD fields. This may show that those policy decisions were not based on empirical data on what books (in terms of the number of author sheets) researchers actually published. It was rather an instrument through which 'too short books' could be excluded from the evaluation, where such short monographs were an easy way to play the system and to obtain more points.

In our view, changing the regulations on the monograph length may be perceived as a type of 'enhancement strategy' of making the evaluation system more coherent and resistant to exploitation of the system gaps. Unlike the 'enhancement strategy', other regulations may be perceived as instruments of 'influencing strategy' that serve to incentivise specific channels of scholarly communication (e.g. the highest number of points for articles in journals with an impact factor) and other areas of scholarly publishing (e.g. publication counting model that favours publishing with researchers external to a scientific unit, which may increase the level of cooperation).

Regarding the publication language, the share of monographs in English was stable for the whole period for all fields except Natural Sciences, where a significant drop occurred in 2013. This drop resulted from the implementation of the regulations for academic promotion procedures: the last chance to be evaluated according to the old criteria was September 2013. Also, the mean number of monographs was stable.

Our analysis shows that the instruments designed for changing publication patterns, on one hand, worked as intended in the area of publications in top-tier journals, and, on the other hand, changed almost nothing in terms of the publication of monographs. If the policy instruments had not changed the publication patterns (either in a good or a bad way) for eight years, this may mean that the instruments were not well designed. Monographs were assessed according to various technical criteria which do not allow for differentiating good from bad quality monographs. Thus, researchers have not followed the incentives and have not changed their publication patterns (e.g. the share of monographs in English did not increase significantly). In our opinion, in the next version of regulations for monograph evaluation, such detailed formal criteria should be abandoned and other instruments should be implemented, such as the ranking of publishers of a peer-reviewed label (Giménez Toledo 2016).

The analysis of patent patterns reveals that the science system in Poland has saturated itself. From our point of view, therefore, it will be difficult to increase the annual number of obtained patents using only policy instruments focused on research evaluation. Giving more points for patents will not encourage scientific units to produce more patents because there is no unutilised research. Thus, aiming to increase more patents should be followed by introducing new instruments, such as programmes implemented by national funding agencies.

Uncovering the relationship between science policy and publication patterns remains a difficult task and is often inconclusive. We are aware that during the analysed decade there were factors other than those indicated in the three areas (i.e. research evaluation, academic promotion procedures and competitive grants) that could have influenced publication patterns. For instance, the growth in the number of journals indexed in the JCR from Central and Eastern European countries with which Poland researcher have a close cooperation or a generational change, manifests itself in the higher share of researchers who had rather English than Russian as a foreign language in school. Moreover, other factors related to mobility, like amendments of air transport availability (Ploszaj et al., 2018) could also influence cooperation and eventually the number of co-authored publications reported by Polish scientific institutions. Nonetheless, it is difficult to build statistical models when there are so many interdependent factors. Similar observations are raised by Aagaard and Schneider (2017), who ask the question of what we can learn from studies on the relation between science policy and perfomance. According to the authors, cases such as the one presented in this paper can improve our general understading of how the mechanisms actually work in a complex scientific system. We share the view that the lessons derived from the various national cases are not directly transferrable from one country to another. It also means that a study from one country should not justify policy decisions in another country. There are always very specific contexts that must be considered in the desigin and implementation of policies.

Conclusion

In this paper we reconstructed the goals of Polish science policy regarding publication patterns from 2007. The diversity of new instruments introduced by the reforms implemented from 2009–2012 show that the Polish government payed attention to how researchers communicate their research and what channels of publications they chose.

Focusing on increasing the effectiveness of science—understood as the share and number of publications indexed in the international databases—worked well. Thus, policy instruments related to this goal should be used for a longer period because Polish researchers still have the capacity to publish more and better publications. Understandably, improving the current system by changing the point scale for *A list* journal publications can encourage researchers to improve their publication practices.

We argue that micro-management within the evaluation regulations is unnecessary. The over-regulated criteria for monographs did not influence publication patterns. Moreover, the micro-management in this area (e.g. indicating the minimum number of author sheets) was not properly expressed by clear scientific policy expectations.

Overall, the Polish experience from 2009 to 2016 shows that science policy can shape publication patterns in a targeted way but only when the instruments are well fitted, science policy expectations are explicitly stated, and instruments are used coherently throughout the evaluation system, academic promotions regulations, and grant agencies. Such a science policy can improve publication patterns. However, policy makers need to remember that the effects of the policy are not immediately visible. Sometimes, it takes a decade to see how researchers have actually adapted to new circumstances and how the policy has influenced their publication practices.

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