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# The Ethos of Science in Contemporary Poland

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**Abstract** Modern science is moving away from Michael Polanyi's vision of 'the Republic of Science' and gradually becoming subordinate to political and economic social institutions. This process is accompanied by changes in the normative structure of science. Poland provides an interesting case for empirical study of the scientific ethos mostly because in a relatively short time it experienced a significant reform of the science system, especially in terms of evaluating and financing scientific work. In this paper we examine whether different sets of values and norms are embedded into the normative structure of science in contemporary Poland. The results of a representative survey conducted among 801 researchers were examined with the use of confirmatory factor analysis and fuzzy clustering. The statistical analysis revealed a great complexity in the normative structure of science that goes beyond the expectations formulated on the basis of the theories reviewed. We identified three distinctive groups of researchers, guided by different sets of values and norms in their professional conduct (academic science, post-academic science and the industrial science) and a cluster of researchers with an unidentified system of principles. We argue that the complexity of the normative structure of science should be taken into account in the decision-making regarding any future reforms of the science system.

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## Introduction

Modern science is moving away from Michael Polanyi's (1962) vision of 'the Republic of Science' and gradually becoming subordinate to political and economic social institutions, as expressed by Janusz Goćkowski (1996), Sheldon Krimsky (2003), Robert Merton (1938b: 328–329), Piotr Sztompka (1986: 48; 2002) or John Ziman (1996, [2000] 2003). As a result, the scientific ethos, understood as an 'affectively toned complex of values and norms which is held to be binding on the man of science' (Merton 1973: 268–269), changes.

In this paper we examine whether in contemporary Poland different sets of values and norms are embedded into the normative structure of science. In so doing, we analyse the results of a representative survey conducted between 2015–2016 among 801 Polish researchers. Poland has experienced a significant economic and political transformation following the breakdown of the Communist regime and thus it serves as an ideal case to study the politically- and economically-triggered evolution of the ethos of science.

We assume that changes in research policy, especially with regard to programs and techniques for subsidizing science and rewarding scholars influenced the existing ethos of science. It is our goal to identify norms and values that guide scientists and assign each of such normative structures to one of the three ethos types: (1) Merton's academic science or (2) Ziman's industrial or (3) post-academic science. Hence, we attempt to answer the following research question: does a universal ethos of science exist in contemporary Poland or are there many sets of values and norms?

The answer to this question has theoretical and practical value. In our view, the sociology of science may give additional insights into the relationship between the anticipated political changes of the science financing system and the actual reactions of academia, not only by focusing on rules and regulations, but also by observing the deeper transformations which occur within the normative structure of science.

We propose the hypothesis that it is the traditional academic science ethos that prevails in contemporary Poland. This assumption is based on the works of Janusz Goćkowski (1978, 1984, 1996, 2005; Goćkowski and Pigoń 1991; Goćkowski and Kisiel 1994, 1999; see also Kisiel 2011), whose diagnoses of the Polish science ethos resemble the Mertonian concept of academic science. Nonetheless, we expect that there are at least two other normative orientations that coexist with the dominant academic ethos: industrial and post-academic. The latter sees a convergence of the academic and industrial research traditions. This expectation is influenced by Sztompka's (1986: 60) argument that the modern, complex scientific system departs from the traditionally dominant Mertonian model of academic science and by Ziman's (1996, [2000] 2003) vision of the post-academic transformation of research conduct that has been at least partly reflected in the recent changes of research policy in Poland.

Such analysis has not yet been carried out. The most comprehensive study of the values shared by the Polish scientists was performed in 2007 on a group of 500 academics (Wójcicka 2008). It showed early signs of change in the traditional Mertonian norms, but authors were cautious in drawing conclusions about the existence of a newer type of ethos. Some of the studies done in other countries were similarly conceptualized. The most recent was an empirical analysis of scientists' endorsement of Mertonian norms performed in South Korea in 2007 (Kim and Kim 2018). The online poll of 644 scientists confirmed that the Mertonian norms are not equally endorsed by all scientists, and that the level of adherence varies e.g. across disciplines, age and seniority. Moreover, the study showed a growing tension between the commercialization of academic science and some academic norms. The same observation about the impact of commercial pressures was formulated by Bruce Macfarlane and Ming Cheng (2008) who conducted a web-based survey in the United Kingdom. Another study by Melissa S. Anderson and colleagues (2010) demonstrated the vast complexity of the normative structure of science in the United States of America. Although newer perspectives on the ethos of science are proposed by other authors (see Grundmann 2013; Kellogg 2006; Kønig et al. 2017; Rodriguez 2007), in none of these studies the concepts of industrial or post-academic science have been fully empirically reviewed.

The remainder of this article is structured as follows: First, we discuss the Mertonian concept of scientific ethos, as well as the industrial and post-academic normative orientation elaborated in the works of Ziman. Then, we present a short overview of science governance reforms that, as we assume, influenced the ethos of science in Poland. In so doing, we focus on the architecture of the Polish research funding system. In the empirical section, data and measures of the normative structure of science are presented. Finally, we describe types of scientific ethos identified in contemporary Poland through statistical analysis based on a structural equation model and fuzzy clustering.

## Normative Structure of Science

### *The Ethos of Science, Its Change and Internalization*

The notion of the scientific ethos is rooted in Merton's concept of social structure. Sztompka (1986: 160) pointed out that the core of Merton's theoretical approach is to consider individuals as 'structurally located' within the network of social relations. According to Sztompka Merton's conceptualization of social structure comprises of three dimensions: normative structure, opportunity structure and ideal structure (Sztompka 1986: 163).

Merton thought of science as a distinct social institution and referred to the normative structure of science as the scientific ethos. He argued that 'like other institutions, science has its corpus of shared and transmitted ideas, values and standards designed to govern the behaviour of those connected with the institution' (Merton 1976: 32). He defined the ethos of science as:

> […] that affectively toned complex of values and norms which is held to be binding on the man of science. The norms are expressed in the form of prescriptions, proscriptions, preferences, and permissions. They are legitimatized in terms of institutional values. These imperatives, transmitted by precept and example and reenforced by sanctions are in varying degrees internalized by the scientist, thus fashioning his scientific conscience or, if one prefers the latter-day phrase, his super-ego (Merton 1973: 268–269)

The idea that scientists share a certain ethos reinforces the concept of the autonomy of science (Merton 1973: 265). The more widespread and stronger a commitment to the ethos is, the less the normative structure of science is susceptible to extra-scientific (e.g., political) influences (Panofsky 2010: 141). The domination of other institutional fields may have both positive and negative effects on the production of certified knowledge. Political, economic and other demands may accelerate the growth of science, contribute to the legitimation of science and the institutionalization of its normative structure (see Merton 1938a; Goćkowski 1996).

A set of values and norms, which is recognized and enacted by a particular scientist, is a reflection of the normative structure of science. It means that scientists' declarations regarding norms professed by them may be utilized as indicators of unobserved, latent construct of the science ethos and can be employed in empirical investigations (see e.g., Anderson et al. 2010). Nevertheless, the correspondence of the scientific ethos with the idiosyncratic inclinations of scientists is never perfect. Norms and values constituting the normative structure of science, norms and values recognized or avowed by a scientist, as well as those that are manifested in conduct, may be different (Sztompka 1986: 56; Goćkowski 1996: 18–19; Barnes 2007). Merton pointed to the distinction between the group-level concept of ethos and its individual-level manifestation. He referred to the degree to which a particular scientist has internalized the ethos of science as the 'scientific conscience' or 'scientific mind' (Merton 1968a: 605). The scientific mind extends to the continuum from shallow or opportunistic to deep acceptance of the scientific ethos (Sztompka 1986: 50). The concept of 'scientific mind' may be used to explain why so many studies document normative violations in science, including biases in evaluating research works, as well as falsifications, and frauds committed by scholars (e.g., Couzin 2006; Fanelli 2009; Ferguson et al. 2014; Redman 2013). It may also be useful in showing more subtle differences between scientists' real behavior and the systems of norms that scientists believe exist or were socialized to obey.

### *Types of Ethos*

#### *Academic Science*

As stated in our hypothesis, we expect that so-called academic science prevails in contemporary Poland, as it is believed to be the 'traditional' or 'normal' set of rules guiding researchers, and also it was used to describe the Polish normative structure of science (see Goćkowski 1978, 1984, 1996, 2005; Goćkowski and Pigoń 1991; Goćkowski and Kisiel 1994, 1999; Wójcicka 2008). Merton described the academic science in its ideal-typical form (Barnes and Dolby 1970: 16; Ziman [2000] 2003: 83). The primary institutional value, legitimizing norms within science, is 'the extension of certified knowledge' (Merton 1973: 270). It may be decomposed into secondary values of objectivity, originality and relevance (see Merton 1968a: 586, 1973: 302, 1982: 214). Objectivity and originality are '[…] complementary, mutually reinforcing, and mutually constraining' (Sztompka 1986: 51–52). The value of objectivity safeguards the 'truth of science', while the value of originality prevents stagnation, fosters the advance of science and sustains academic freedom (Ziman 1996: 68; [2000] 2003: 182, 204). The value of relevance is directed outside science and ensures that it responds to the pressing problems and the needs of society, and not simply to the pursuit of knowledge for its own sake (Merton 1982: 214).

Four main norms that Merton presumed accurately described the work of scientists are: communism, universalism, disinterestedness and organized scepticism (Merton 1973: 270). These are mainly recognized through the acronym 'C.U.D.O.S'[1]. This set of scientific norms has been extended by numerous researchers, and by Merton himself (see Anderson et al. 2010; Barber 1952; Stehr 1978: 174–175).

The norm of 'communism' implies that research findings are a product of social collaboration, and as such should be the common property of the scientific community (Merton 1973: 273–274). This norm ensures that scientific knowledge is placed under scrutiny, and thus contributes to the achievement of the value of objectivity (Ziman [2000] 2003: 98, 105).

'Universalism' denotes 'preestablished impersonal criteria' in appraising the scientific truth-claims. Universalism requires that acceptance or rejection of truth-claims does not depend on the personal or social attributes of the scientist who publish them (Merton 1973: 270). In Merton's view, 'universalism' reinforces the autonomy of science. When other social institutions gain predominance over science, science lacks its autonomy, and scientific ethos is subjected to strain (Merton 1973: 271).

'Disinterestedness' refers to the characteristic of science as a social institution and '[…] points to a distinctive structure of control exercised over the individual motives of scientists' (Stehr 1978: 174; see also Merton 1973: 276; Wunderlich 1974: 374–376). Disinterestedness diminishes the personal or subjective bias as the 'consensual objectivity' is produced by the ethos of science. It relieves scientific knowledge from subjective elements by mutual reinforcement of 'communism', 'universalism' and 'disinterestedness' (Ziman [2000] 2003: 155).

'Organized scepticism' is an epistemic requirement that describes the critical scrutiny of research claims. Merton argued that academics exercise caution in asserting the results of their inquiries, do not follow any dogmas, and even overthrow established beliefs by questioning them (Merton 1973: 277–278; Ziman [2000] 2003: 246–248). This norm ensures objectivity and triggers debates over the

[1] These four norms were originally presented by Merton in his article 'Science and Technology in a Democratic Order' (1942). In Ziman's ([2000] 2003) interpretation 'O' stands for originality which was described by Merton in his later work (1973: 297–302).

state of knowledge and the directions of its development (Macfarlane and Cheng 2008: 69; Ziman [2000] 2003: 249).

*Industrial and Post-Academic Science*

Ziman states (1996: 67) that these Mertonian norms do not correspond entirely with newer processes of knowledge production (Ziman 2000: 188). He mainly refers to the practical-problem-solving 'Mode 2 knowledge production' (Gibbons et al. 1994; Nowotny et al. 2001) that emerged in the mid-20th century outside of academia. Ziman names other methods of scientific conduct 'industrial' or 'post-industrial'[2], as they accentuate adhesion to the business sector, especially corporate R&D laboratories. The main objective of industrial science is to produce knowledge with 'clearly foreseen or potential uses' (Ziman 2002: 397) for a 'variety of organizations strongly linked to the major interest groups of society at large' (Ziman [2000] 2003: 173). Further on, it implies the commercialization and specialization of knowledge. The hybrid system that fits neither the 'pure' academic nor the industrial ethos of science is called 'post-academic' (Ziman [2000] 2003: 206). This new form of scientific conduct emerged as a result of the science and technology policy (Ziman 2000: 75), and 'is becoming the dominant mode, even in relatively "basic" fields of research' (Ziman 2000: 188).

Industrial science has its own normative orientation. The set of norms and values of the industrial sphere is referred to through the acronym 'P.L.A.C.E.' (proprietary, local, authoritarian, commissioned, and expert). Industrial norms permeate academic science, thus their description shall be followed by a portrayal of their presumed influence on the post-academic system.

The first of the five distinctions – the 'proprietary' character of industrial science – opposes the norm of 'communism' and describes results of research as 'owned' rather than 'shared' within a community of scientists. Discoveries made in industrial organizations are protected by property rights and do not contribute to public knowledge (Ziman 1996: 71; [2000] 2003: 114). In the post-academic setting the proprietary character of research affects the open distribution of science (Ziman [2000] 2003: 116).

The norm called 'localism' opposes Merton's 'universalism'. Scientists working for companies are expected to solve narrowly defined practical problems, thus their research results cannot be generalized as relevant to broader phenomena (Ziman 1996: 71–72, 77–78; [2000] 2003: 78–79) or even to be implemented in a different laboratory (Ziman [2000] 2003: 101). In order to defend the academic norm of universalism, post-academic scholars choose research problems that are partly local and partly universal (Ziman 1996: 71–72, 77).

[2] Ziman states that industrial science was developing simultaneously with the academic science, and currently is evolving towards the post-industrial system. This new way of scientific conduct differs from its earlier form because it is 'substituting "market" competition for "command" management' (Ziman 1996: 75–76; see also Ziman [2000] 2003: 80–81). If not explicitly differentiated, we use the term industrial to describe the industrial and the post-industrial normative structure.

Industrial science is ‘authoritarian’ rather than ‘disinterested’, and this accentuates the deprivation of autonomy of science (Ziman [2000] 2003: 79) and existence of a bias in science (Ziman 1996: 72–73). In the post-academic setting the actions of researchers are controlled and adjusted by external bodies that execute their powers over the initiation of research, publication and implementation processes. When other social institutions dominate over science in such a way then alternative goals, such as financial effectiveness, prevail (Ziman 1996: 72–73).

Finally, while in academic science ‘originality’ allows all of the other norms to function within a system that rewards the priority of discovery, in industrial science research is ‘commissioned’. Thus, freedom of choice regarding the topics of scientific inquiry is not achievable (Ziman [2000] 2003: 79, 178, 188, 204–209). Industrial scientists should be characterized as ‘experts’ and not sceptical seekers of abstract truths, as they are employed to solve problems within narrowly specialized fields of science (Ziman [2000] 2003: 79). Similarly, the post-academic scientists react to the expectations of research financing institutions. The external control over science may be further enhanced by the scarcity of public funds for research (Ziman 1996: 70, 73; see also Ziman 1994).

As Krimsky (2006: 28) noted, for Ziman the loss of some means and goals of traditional science is not ‘epistemologically connected’ to the demise of its objectivity or integrity: ‘post-academic scientists still formulate and try to solve practical and conceptual problems on the basis of their shared belief in an intelligibly regular, not disjointed, world outside themselves’ (Ziman [2000] 2003: 330). The norm that diminishes the most is ‘disinterestedness’, but the effect of such a loss might be mitigated by the operation of communalism, universalism and scepticism (Ziman [2000] 2003: 174). Ziman foresees an entanglement of normal science in networks of other social institutions (Ziman 1996: 72, 74).

The significance of Merton’s and Ziman’s characterizations of the normative structure of science has been much disputed (e.g., Barnes and Dolby 1970; Gieryn 1983; 1999; Hooker 2003; Krimsky 2003; Mulkay 1976a, b; Rodriguez 2007; Stehr 1978; Toren 1983). So has the idea of a change in ethos. The proposition that one model of the production of knowledge is replaced by another appeared to contradict the facts (Shinn 2002). However, Ziman was careful to characterize academic and industrial sciences as coexisting, and slowly changing into post-academic. He also stipulated that these processes were too recent to largely affect the normative structure of traditional science (Ziman [2000] 2003: 330). Nevertheless, such criticism only emphasizes the need for empirical investigation of this theory.

## The System of Science in Poland

In Poland a new system of science governance emerged after over two decades of transformation, and since 2007 it has been constantly evolving towards a performance-based model (see Hicks 2012). Julita Jabłecka and Benedetto Lepori (2009: 697, 702) have divided this 20-year-long period in Polish history into three phases: ‘radical change in a short time’ (1989–1991), ‘substantial stability’ (1991–2000), and ‘gradual changes leading to further restructuring of research policy and funding’ towards solutions implemented in other European states (2000–2007). To this we should add a period marked by an even deeper systemic reform of the entire funding system that promotes institutional and individual competitiveness (since 2007, mostly in 2010–2011), which we assume may have had the biggest impact on the normative structure of science in contemporary Poland.

In 1990, just a year after the end of communism, a new law on higher education was introduced, bringing back the principle of the autonomy of the university and academic freedom[3]. In 1991 the State Committee for Scientific Research was established, granting funds to research organizations or teams, mostly in the form of statutory (institutional) funding (Kozłowski 2004). This committee made merit-based funding decisions up to the mid-2000s, when it was replaced in this function by the Ministry of Science and Information Technology and then by the newly established Ministry of Science and Higher Education (see Jabłecka and Lepori 2009: 702), which remains the core decision-making institution in the field of science to this day. Goćkowski observed that in this phase of changes the previously preserved axionormative continuity in science had been interrupted by the growing demand for what he called 'expert science'. It had more practical meaning than the traditional science and consequently a normative structure that resembles Ziman's industrial science (Goćkowski 1996: 330–331).

The first reforms of the science system, although apposite at the time, brought few meaningful economic results. Just after accession to the European Union, Poland was one of the least innovative economies in the European Community with R&D intensity amounting to 0.56% of GDP in 2005 (in comparison to 1.74% average of the 28 current EU member states) (Eurostat 2017a, b). The share of the appropriations or outlay for research and development in central government budget (the GBAORD) remained lower than in the case of most other EU member states (Eurostat 2017a, b).

In order to increase the effectiveness and transparency of science funding process, the government decided to introduce new models for the distribution of grants, based on solutions promoted by the international organizations (see Hicks 2012; OECD 2010). The leaders of this reform also accentuated the need to commercialize research results, which, it was presumed, could boost the economy. This belief was based on discourse around the 'knowledge-based' economy (see Mowery and Sampat 2004: 209–239) and the 'Triple Helix' doctrine (see e.g., Etzkowitz and Leydesdorff 2000; Etzkowitz 2003). It can be argued that these new policies aimed at strengthening the links between science and business further enhanced the need for the expert science and, at least to some extent, begun a merger of the academic and the industrial science norms.

In 2007 the National Centre for Research and Development (NCRD) began operation – an agency allocating grants mostly for applied research and ensuring the transfer of knowledge to the commercial sector. Then, in 2010, the funding infrastructure

[3] These concepts were present in the Polish system of higher education before the Second World War, e.g., among scientists belonging to the Lvov-Warsaw school (Jabłecka and Lepori 2009: 700; Dylus 2010: 136).

was enhanced by the establishment of the agency independently deciding on the allocation of funds for basic research – the National Science Centre (NSC). During the period 2010–2011 a series of five legal acts further changed the public science funding system. At present it is almost equally divided between two models of academic funding: institutional and project-based (40% and 60% of funds respectively, see Klincewicz and Szkuta 2016). Within the first, research organizations and HEIs receive funds for statutory activities taking into account the outcomes of their parametric evaluation. In the project-based model, researchers compete individually, or in teams, for limited research funds granted by the agencies. In the case of the NSC research topics are usually chosen by scientists themselves, but in the case of the NCRD most often scientists adjust their research proposals to fit into general specifications provided by the agency (e.g., collaborate with the business sector in order to receive funds). This shift in the model of financing research could be interpreted as an encouragement for scientists to focus on solving more narrowly defined, local and practical research problems. Some forms of research performed by academics are now 'commissioned', and this is done mostly by the NCRD. We argue that, at least in the case of applicable research, the autonomy of science was reduced as the top-down, 'authoritarian' approach to research proposals became an accepted norm.

Furthermore, although the Polish system can be described as moderately research-quality oriented, in a situation where there is permanent underfinancing of the sector, it may seem excessively competitive (see Tomczyńska 2016; Dakowska 2017: 88). The analysis performed by the National Information Processing Institute[4] confirmed that during the period 2014–2016 grants of the NSC were mostly distributed among research units with the highest parametric rating. The participation in research projects is in turn taken into account during the parametric evaluation, and thus the outcome of the competition for grants further increases (or decreases) chances of obtaining funds for statutory research. This process parallels the 'Matthew effect' (see Merton 1968b, 1988) and is politically accepted, because, following the logic of new public management and liberalism, it ensures that limited resources are directed to those institutions, which are expected to generate the biggest social and economic returns from the public investment in science. It however means that these institutions are more eager to introduce stricter managerial control over research processes, and that some scholars are more prone to follow guidelines imposed on science by other social institutions (polity and economy). In the new legal milieu of such a tense competition for public funds, the normative structure of science is expected to change further, reinterpreting its accepted level of autonomy, and incorporating industrial norms, as stipulated by the investigated theories.

[4] The estimates are based on data from the POL-on database (www.polon.nauka.gov.pl), and the ZSUN/OSF database (www.osf.opi.org.pl).

## Data, Methods and Statistical Analysis

*Data*

We performed an investigation of the Mertonian and Ziman's concepts through empirical analysis, based on a survey conducted from December 2015 to January 2016 on a representative sample of academics and governmental researchers in Poland. The questionnaire was designed to collect data about topics such as: the ethos of science, attitudes towards reforms of the science system, research productivity of scientists and their assessment of success factors in science. The empirical data were gathered by the IQS research company via computer-assisted personal interviews. The population was defined as a group of persons holding a Ph.D. degree or higher, professionally carrying out scientific research, and working in higher education institutions (both: private and public), governmental research institutes or institutes of the Polish Academy of Sciences (see Table A1 from the online appendix). It did not include industrial researchers, who do not function within the system of science and therefore are not relevant for the theories under investigation in this paper. The sampling frame was formed based on the most up-to-date and accurate data on scientific institutions and academics in Poland collected by The National Information Processing Institute (OPI PIB).

The survey sample of 801 researchers was designed based on a complex two-stage disproportionate stratified random sampling scheme. It mapped such population characteristics as: type and size of a research organization or HEI, field of science, academic degree and gender (see Table A1 from the online appendix). Since the probabilities of selecting individuals were unequal, design weight and post-stratification weight were both applied during statistical analysis. Data from a questionnaire were supplemented with selected characteristics of respondents from the sampling frame database. Missing values were treated with the MICE procedure in the calculations.

*Measurement*

Prior to the construction of the survey questionnaire, 18 in-depth interviews (IDI) were conducted in order to determine the exact wording of statements which later became indicators of examined latent variables. Interviewees with various degrees and academic titles were selected for this exploratory part of the research, taking into account their field of science and the type of scientific institution they represented. Furthermore, the survey questionnaire underwent a pilot study in order to limit measurement errors.

Respondents were given 10 statements for evaluation on an 11-point numeric scale, where 0 meant 'strongly disagree' and 10 – 'strongly agree'. Table A2 from the online appendix presents the names of the variables and the exact wording of statements (translated from Polish) along with the corresponding dimensions of latent variables and selected descriptive statistics.

The norm of 'communism' (Merton 1973: 273) was measured by respondents' acceptance of the statements: 'Scientific discoveries are the property of the whole community of scientists, so keeping them secret or sharing them in exchange for money is unethical' (S3) and 'The results of scientific research should be available to all interested parties' (S10). The norm of 'universalism' was measured by respondents' acceptance of the claim: 'Scientific statements should be evaluated solely on the basis of their compliance with empirical data and previously confirmed knowledge, never on the basis of who claims them or for what specific reasons they are claimed' (S1). The norm of 'disinterestedness' was measured by respondents' acceptance of the statement: 'Research activities should be solely devoted to seeking the truth' (S5). 'Organized scepticism' was measured by respondents' agreement with the statement: 'The scientist should be distrustful of any universally shared judgments, because only with such a sceptical attitude the development of science is possible' (S7).

The counter-norm of 'communism' is 'proprietary science'. This aspect of the industrial and post-academic science ethos was measured by the level of acceptance of the statement: 'Scientifically produced knowledge should be owned by the sponsor of research, even if such ownership limits the possibilities of its lawful use by others' (S9). Industrial and post-academic science is characterized as 'local'. This practical orientation is the antithesis of universalism and thus it was measured by respondents' acceptance of the statement: 'Science should primarily be used to solve practical problems of a limited scope – the utility of general theories is small' (S11) and disagreement with the statement: 'Science should expand our understanding of reality, regardless of whether its findings have immediate practical application' (S12). The distinctive character of the industrial and post-academic ethos of science is the acceptance of 'authoritarian' control and strict management of the production of knowledge. This attitude was measured by the level of acceptance of the statement: 'Scientific work should be subject to strict control and management, as in industrial companies' (S13), and the attitude towards 'commissioned' research by the statement: 'Research ordered and financed by private companies, even if methodologically correct, is generally less credible than publicly funded research' (S16). The 'expert' character of researchers working within industrial and post-academic science was measured by the response to the statement: 'With the current extent of scientific knowledge, only limiting the field of research to narrow specializations allows for new discoveries' (S15).

### *Statistical Method*

In order to answer the research question and examine the complexity of the normative structure of science in contemporary Poland two main statistical techniques have been employed: structural equation modelling and fuzzy clustering. The former allows testing the theoretical model of the science ethos. The obtained results were evaluated to see how well the postulated model matches empirical data, and the model's parameters were interpreted to assess their consistency with theoretical assumptions. The structural equations model took the form of confirmatory factor

**Table 1** CFA model parameter estimates

| Factor loadings: | | | b | Standard Error | p value | Beta |
|---|---|---|---|---|---|---|
| Academic ethos | <- | Ethos of science | 1,000 | | | 0,816 |
| Communism | <- | Ethos of science | 1,138 | 0,129 | 0,000 | 0,849 |
| Ethos of science | <- | Scientific mind | 1,000 | | | 0,707 |
| Industrial science | <- | Scientific mind | 1,816 | 0,205 | 0,000 | 0,876 |
| S3 | <- | Communism | 1,000 | | | 0,633 |
| S10 | <- | Communism | 1,188 | 0,133 | 0,000 | 0,733 |
| S9 | <- | Communism | −0,587 | 0,112 | 0,000 | −0,361 |
| S5 | <- | Academic ethos | 1,000 | | | 0,663 |
| S1 | <- | Academic ethos | 0,604 | 0,057 | 0,000 | 0,463 |
| S7 | <- | Academic ethos | 0,560 | 0,073 | 0,000 | 0,337 |
| S12 | <- | Academic ethos | 0,651 | 0,057 | 0,000 | 0,559 |
| S11 | <- | Academic ethos | −0,651 | 0,122 | 0,000 | −0,352 |
| S13 | <- | Academic ethos | −0,317 | 0,097 | 0,001 | −0,189 |
| S11 | <- | Industrial science | 1,000 | | | 0,648 |
| S9 | <- | Industrial science | 0,733 | 0,113 | 0,000 | 0,494 |
| S13 | <- | Industrial science | 0,578 | 0,089 | 0,000 | 0,412 |
| S5 | <- | Industrial science | 0,661 | 0,101 | 0,000 | 0,408 |
| S12 | <- | Industrial science | −0,256 | 0,050 | 0,000 | −0,263 |
| Covariances: | | | covariance | Standard error | p value | correlation |
| Ethos of science | ~~ | Industrial science | −0,774 | 0,268 | 0,004 | −0,774 |

Factor pattern coefficients and covariances of latent variables

<- regression; ~~ covariance

analysis (CFA). Fuzzy clustering allowed for the identification of the main forms of the normative structure of science and thus the verification of the hypothesis that the academic science ethos prevails in contemporary Poland, but that it incorporates norms and values typical of the industrial science system, and that there are at least two other normative orientations that coexist with the dominant academic ethos: industrial and post-academic.

## Results

### *Modelling the Ethos of Science on an Individual Level*

The openness of scientific conduct was defined by measures of the 'communism' norm (S3, S10) and its counter-norm – 'proprietary knowledge' (S9). The remaining norms of scientific ethos reflect a common first-order factor denoted as 'academic science'. It was measured by six observed variables: disinterestedness (S5), universalism (S1, S12), scepticism (S7), and the relevant counter-norms of local (S11) and authoritarian (S13) science. The latent factor representing the 'industrial science'

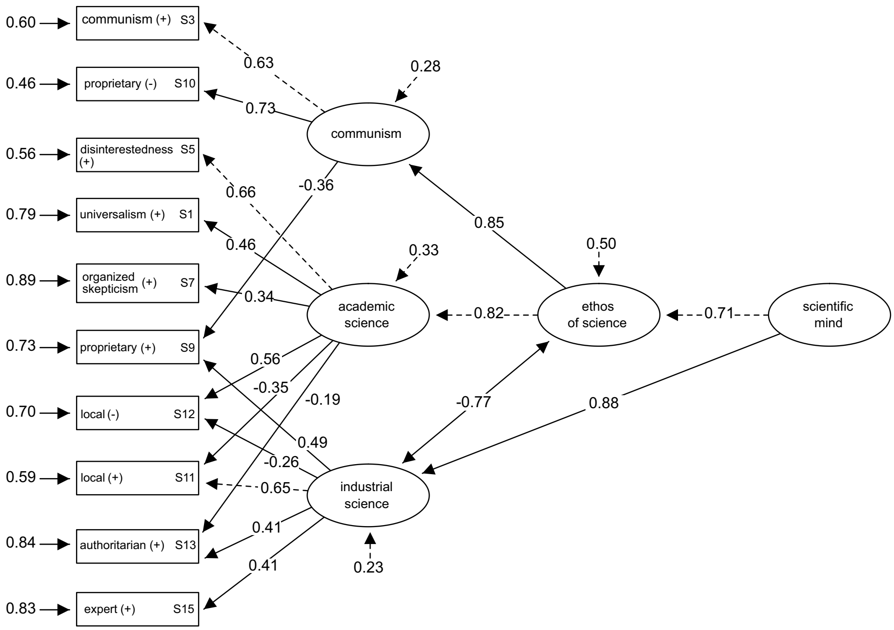


**Fig. 1** Ethos of science / ethos of scientist. Standardized CFA model estimates. The path diagram represents a set of regression equations where the observed variables serve as dependent variables, while latent variables and error terms as independent variables. The numbers represent standardized regression coefficients that inform of the direction and strength of the relationship between dependent and independent variables. The value of observed variables is assumed to be the outcome of unobserved phenomena and measurement error. The SEM allows not only to estimate the regression parameters but also the values of latent variables. One-headed arrow lines represent regressions, double-headed arrow lines represent covariances or correlations, and dashed lines represent fixed factor loadings employed to estimate the structural model. ML estimator, multiple imputations with MICE procedure, m=10. Chi2 = 104,2, df = 31, p < 0,000; GFI = 0.976; AGFI = 0.956; SRMR = 0.176; RMSEA = 0.051; lo c.i. = 0.04; hi c.i.= 0.063

ethos was measured by norms of proprietary (S9), local (S11, S12), authoritarian (S13) and expert (S5) science[5]. For each first-order latent variable, one factor loading has been fixed in order to identify the model, and that variables' scale has been applied for respective latent variables (see Table 1). This was marked on the path diagram using dashed lines (see Figure 1).

The structural part of the CFA model defines relations between latent variables. The traditional 'ethos of science' was defined as a second-order factor measured by the latent variables of 'communism' and 'academic science'. The structural model allows the 'ethos of science' and 'industrial science' latent variables to covary, i.e., the covariance parameter can be estimated. This was marked by double-headed arrow line on the path diagram (see Figure 1). The free covariance parameter reflects

[5] The measurement model of the industrial science does not comprise the indicator of commissioned knowledge. The indicator has been removed in the process of model building due to low correlation with the latent variable.

opposing norms denoted by the two latent variables. The 'ethos of science' and the 'industrial science' latent variables load on a third-order latent factor, which denotes the 'scientific mind' (or 'scientific conscience') – an important concept in the Merton's theory (see Merton 1968a: 605). As we have explained earlier in this paper, it is an individual-level manifestation of the ethos. With regard to the structural model, this factor represents the variance unexplained by the co-occurrence of the academic science and industrial science factors and allows detection of the hybrid types of ethos, i.e., the post-academic science, which gathers norms of the both normative orientations.

This form of structural model was established through a model generating approach. It involves the modification of an initially specified model, based on modification indices, in an effort to improve the model fit (Schumacker and Lomax 2016: 107). The goal was to find a model that fits the data well and has substantive theoretical meaning. The final form of the model was accepted based on its good reflexing of the theoretical assumptions, the model fit measures and the stabilization of the model parameters after the introduction of the third-level latent variable ('scientific mind').

The 'communism' and the 'academic science' latent variables are expected to have positive factor loadings on the 'ethos of science'. Since 'industrial science' is defined in terms of counter-norms of scientific ethos the two second-order latent variables are expected to have high negative covariance. The third-order latent variable 'scientific mind' loads on both 'ethos of science' and 'industrial science'. The factor loadings are expected to be positive. This is because 'scientific mind' represents individual-level expression of the normative structure of science that may include elements of both the academic and the industrial science ethos. During our analysis it became apparent that in order to answer the research questions adequately, we should also take into account that it is rarely the case that scientists fully internalize norms and values dominant in particular institutional settings. On the one hand, it is possible that members of scientific community internalize both: elements of the academic and the industrial ethos of science – a condition defining post-academic science (Ziman 1996). On the other hand, opportunistic adaptation or 'non-ethos' is also a valid outcome in a situation where none of the above axio-normative constructs are internalized (see Merton 1968a: 605; Sztompka 1986: 50, 56).

The parameters of the structural equation model were estimated using the maximum likelihood (ML) estimator[6]. Missing values were imputed with the multivariate imputation by chained equations (MICE) algorithm (n = 10 imputations)[7]. In

[6] Statistical analysis and data transformations were conducted with R Language and Environment for Statistical Computing (R Core Team 2014). The structural equation model was estimated using the 'lavaan' package (Rosseel 2012), missing data was imputed with 'mice' package (Van Buuren and Groothuis-Oudshoorn 2011), and pooled model parameters were derived using the cfa.mi() function from 'semTools' package (semTools 2016).

[7] The missing values were imputed in order to avoid a reduction of sample size being included in the next analytical step, i.e., fuzzy clustering analysis.

order to assess the model fit, several fit measures were employed[8]. The model fit is satisfactory (Chi2= 104.2, df = 31, $p < 0.000$; GFI =0.976; AGFI = 0.956; RMSEA = 0.051, RMSEA lower 90% C.I. = 0.04, RMSEA upper 90% C.I. = 0.063). The goodness-of-fit index indicates that over 97% of the observed variance/covariance matrix is predicted by the model (see Schumacker and Lomax 2016: 113–114; see also Hu and Bentler 1999 for model fit cutoff criteria).

The results of the pooled ML estimation are presented in Figure 1, Table 1, and in Tables B-E from the online appendix. All of the parameter estimates are of the expected magnitude and direction and are significantly different from zero ($p < 0.01$).

The measurement sub-models of first-order latent variables show that the indicators well reflect the latent constructs (see Table 1). The explained variance of observed variables ranges from R2 = 0.54 to R2 = 0.114, with the lowest coefficients for variables measuring only one latent variable (see Table D from the online appendix). Moreover, factor structure coefficients[9] support a high measurement validity. Only the counter-norms indicators of each latent constructs have low negative correlation coefficients with corresponding factors (see Table E from the online appendix). This result supports the theoretical validity of the measurement sub-models.

The latent variables of 'communism' and 'academic science' load strongly on the 'ethos of science' with standardized factor loadings of 0.849 and 0.816, respectively. As expected, the 'ethos of science' and 'industrial science' latent variables are negatively correlated with the correlation coefficient of −0.774. Both of these latent constructs have strong positive factor loadings on third-level factor, i.e., the 'scientific mind' (see Table 1). These structural sub-model parameters support the expected directions and magnitude of relationships between latent variables.

### *Types of Scientific Ethos in Contemporary Poland*

Fuzzy k-means clustering allows the identification of the main forms of the normative structure of science and thus refutes the hypothesis identifying only three types of scientific values and norms. The clustering shows instead that there are four types of normative structure of science in contemporary Poland: academic (which prevails, as stated in hypothesis), post-academic, industrial, and opportunistic adaptation (termed here 'non-ethos'). Latent variables derived from confirmatory factor analysis have been saved in the dataset as regression scores. The 'ethos of science' and 'industrial science' latent variables were used in clustering analysis.

The clustering analysis was based on fuzzy k-means clustering with entropy regularization of k=4 clusters and an entropy parameter of 0.7. The entropy regularization allows the use of the artificial fuzziness parameter to be avoided. It is replaced by the entropy, i.e., 'degree of uncertainty' (see Li and Mukaidono 1995).

8 Because the original method to find the baseline model does not work for models estimated on data with MICE-imputed missing values, fit measures relying on the baseline model could not be used.

9 The correlation coefficients between observed and latent variables.

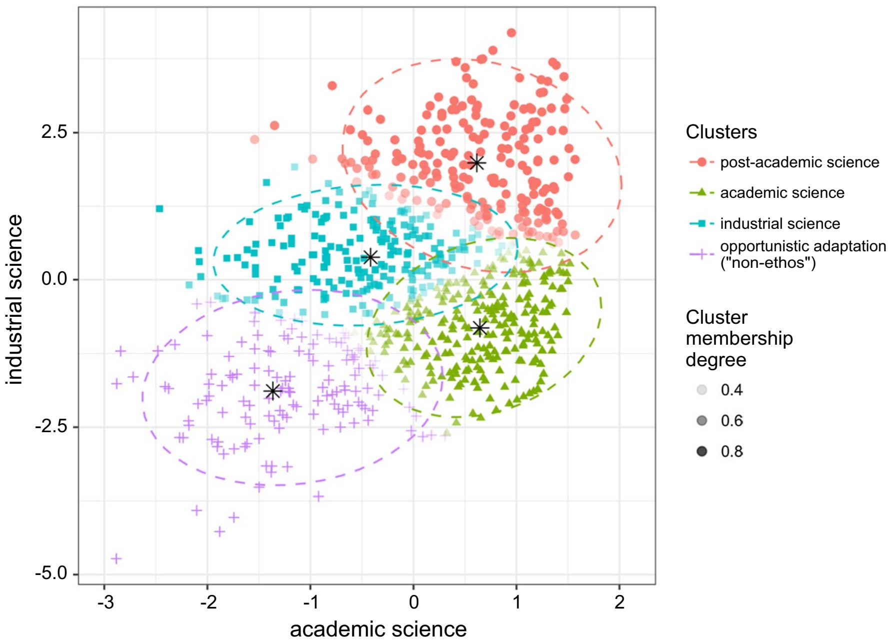


**Fig. 2** Type of ethos in the field of science. Fuzzy clustering with entropy regularization. * - cluster centres. k = 4 clusters, entropy parameter = 0.7; Partition coefficient (PC) = 0.824, Modified PC (MPC)= 0.766, Xie and Beni Index (XB) = 0.297

**Table 2** Cluster centres. Fuzzy clustering

| | Ethos of academic science | Industrial science | N |
|---|---|---|---|
| Post-academic science | 0,615 | 1,986 | 203 |
| Academic science | 0,645 | −0,814 | 254 |
| Industrial science | −0,415 | 0,381 | 196 |
| Opportunistic adaptation (non-ethos) | −1,364 | −1,887 | 147 |

Respondents were assigned to a cluster according to the maximal membership degree

The fuzzy classification indices allow the results to be accepted. The partition coefficient (PC) = 0.824, modified PC (MPC) = 0.766, Xie and Beni Index (XB) = 0.297 and partition entropy (PE) = 0.302. The partition coefficient measures how close the fuzzy solution is to the corresponding hard solution, i.e., the solution classifying each object into the cluster with the largest membership.

The results of the cluster analysis are graphically presented in Figure 2, where the ethos of 'academic science' is presented on the x axis and the ethos of 'industrial science' is presented on the y axis. Each point reflects an individual

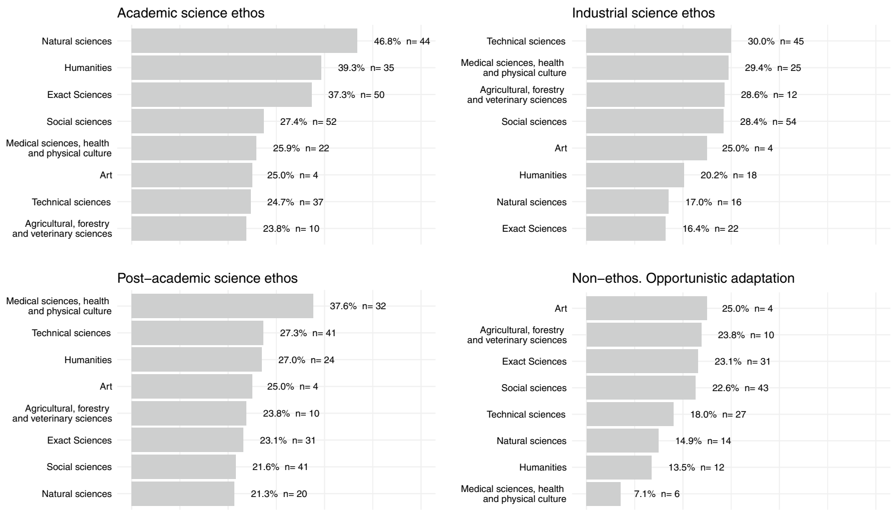


**Fig. 3** Proportion of respondents belonging to a cluster within scientific disciplines. Maximum cluster membership degree criterion was used for assigning respondents to clusters

respondent, with point shapes representing clusters and point transparency representing the degree of cluster membership.

The four clusters can be interpreted in line with theoretical assumptions. Respondents with high scores on the 'ethos of academic science' and low scores on the 'industrial science' axis form a distinct cluster with the centre at 0.645 for 'academic science ethos' and −0.814 for 'industrial science ethos' (see Table 2). This cluster may be interpreted as 'academic science', since it consists of respondents who accept the norms of Merton's academic science ethos and reject the norms defining the normative structure of industrial science. It includes 254 respondents who have the highest membership degree for the cluster. This cluster is most strongly represented among fields of science such as: natural sciences, humanities, and exact sciences (see Figure 3).

The next cluster comprises respondents who accept norms typical for the 'academic' and for the 'industrial' science ethos (cluster centre at 0.615 and 1.986 respectively). It consists of 203 respondents with the highest membership degree. We interpret this cluster as representing the 'post-academic' science ethos (see Table 2). The proportion of respondents belonging to this cluster is the highest among medical sciences (see Figure 3).

The third cluster consists of respondents who score high on the 'industrial science ethos' axis and low on the 'academic science ethos' axis. The cluster is most strongly represented among respondents from technical sciences, medical sciences, agricultural sciences, and social sciences (see Figure 3). The cluster centre is defined by mean values of 0.381 and −0.415, respectively, thus we interpret it as an 'industrial science' cluster. It includes 196 respondents with the highest membership degree.

Finally, there are 147 respondents that reject both norms of the academic science and the industrial science (cluster centre at −1.364 and −1.887, respectively). We interpret this form of normative structure within the field of science as opportunistic adaptation or 'non-ethos'. It is quite common among researchers from the agricultural, exact and social sciences, but rare among medical sciences and humanities.

The preliminary analysis showed that these clusters do not differ when it comes to such scientists' characteristics as: gender, field of science, type of research (basic, applied, or R&D works), and type of employing institution. However, the industrial ethos is not as often embraced by professor as in the case of other ethos types. Furthermore, respondents belonging to the 'academic' and 'non-ethos/opportunistic adaptation' cluster can be distinguished by a lower than average overall assessment of the 2010–2011 reforms in the science governance and funding. The 'non-ethos' cluster is also characterized by a higher than average research productivity (number of research papers, including those published in a foreign language, participation in research projects, patent applications, and obtained research grants). The differences in productivity are particularly pronounced among scholars from natural and technical fields of science.

## Conclusions and Discussion

The results of the study show a vast complexity in the normative structure of science, one that goes beyond the expectations formulated in our hypothesis. We identified four distinctive groups of researchers who declare that they are guided in their professional conduct by different sets of values and norms. When interpreting the results, one has to remember that these normative orientations are recognized by the Polish scientists, but may vary from norms actually followed by them (see section "Types of Ethos"). In this regard the identified normative systems are ideal types, that may give an insight, but not a full picture of the far more complex normative structure of science.

As anticipated, the academic norms attract the strongest support among researchers in Poland. This is not surprising, given not only the widely emphasized attachment to the idea of an autonomous university by academics in Poland, but also in regard to the growing interest in open science movements (Ostaszewski 2014), which are largely in line with Mertonian norms, especially with the norm of 'communism'.

It is now evident, however, that the post-academic science ethos is shared by the second major cluster of researchers. This type of ethos seems to be promoted by the government-level decision-makers. In contemporary Poland the importance of the project-type funding distributed by the NSC and the NCRD is growing, and the economic utility of research projects is strongly emphasized. The extending control over scientific conduct diminishes some aspects of the traditionally defined autonomy of science. At the same time, excellence of scientific work (enhanced by e.g., the norm of 'organized scepticism' and the values of objectivity, originality and relevance) or the open circulation of science (i.e., norms of the academic science), are rewarded. Researchers, who belong to the cluster of post-academic science, may be characterized as individuals well-adjusted to the public system of financing science. Our preliminary analysis shows that they appreciate the direction of the 2010–2011 reforms more often than scientists belonging to the academic and the 'non-ethos/opportunistic' cluster.

Given the quite recent development of policies that strengthen linkages between universities and companies, it is intriguing to observe that the normative structure of science comprises also researchers belonging to the industrial science ethos. This finding indicates the readiness of many scientists (mostly those without a professorship) to cooperate with business. Meanwhile, the lack of interest in commercial activities on the part of Polish scientists is indicated by decision-makers as one of the reasons for low innovativeness of Poland (Matusiak and Guliński 2010, see also Marklund et al. 2017). Thus, our research suggests concentrating on the systemic barriers to academic-driven innovativeness.

Although we did not include this assumption in our hypothesis, the mosaic of normative structure of science is complemented by a fourth cluster of researchers who do not share any specific ethos. Merton's theory of normative structure suggests that this may be due to the lesser extent of internalization of scientific ethos amongst these academics or even due to the normative disorientation that may trigger deviant behaviour directed towards socially prescribed goals (Merton 1973: 308, note 51). It may also be argued that the scale and scope of the 2010–2011 reforms, unprecedented since the 1990s, have led to a split between the vision of science presented by some researchers and the vision of the legislature (Kwiek 2015: 242). This observation gains support in preliminary analysis of the data that showed lower than average support for reforms of the science system among scholars from the 'non-ethos' cluster. It is also intriguing that these scientists are more productive than researchers from other clusters in terms of research results. It seems that they aim at gaining culturally legitimate goals, but find insufficient support in institutionalized norms for attaining these goals, which is a situation described by Merton as a type of individual-level adaptation to anomy, i.e., innovation (Merton 1938c). It develops when the behaviour of many people is not subject to normative constraints and is primarily dictated by considerations of efficiency. Under such circumstances norms lose the ability to regulate individual behaviour, and effectiveness becomes the main principle organizing conduct (Merton 1938c). In regular circumstances science is protected against such deviations by the ethos of academic science, which intensifies the critical review of other scientists' work and also efforts to replicate others' results (see Zuckerman 1977). However, once economy or polity dominates over science or there is another, incompatible, ethos within the science system (e.g., industrial norms), the traditional scientific ethos loses its ability to regulate individual behaviour (see also Anderson et al. 2010: 391). It may be further anticipated that this is how anomie (or fatalism) emerges (see Bieliński 2013, 2015, 2016). This phenomenon deserves further studies as anomie may cause the failure of science policy directed towards 'non-ethos or opportunistic' cluster of researchers.

The robustness of the values and norms endorsed by the Polish researchers show the usefulness of a theoretical framework that links Mertonian academic science ethos with Ziman's industrial and post-academic science ethos. The findings of this study contribute to the contention that different principles and cultures coexist within the science community, and this is an argument that must be taken into account by policymakers. The results of this study may be used to design and communicate changes in the science and higher education system accurately, especially when recognizing and rewarding scientific achievements. The prevailing traditional science ethos clashes with the demands and expectations of science funding agencies in Poland, and also with the utilitarian approach towards research that prevails in the discussions about the future of the publicly-funded science. In contrast, researchers with the industrial ethos of science require a greater flexibility in evaluating scientific work e.g., by broadening the definition of a scientific project. Similarly, a set of new policies towards researchers from the 'non-ethos' cluster is much needed in order to detain the process of normative disintegration and preserve their ability to produce research results.

It is important to acknowledge that although researchers who represent particular fields of science are inclined to share a certain ethos of science, the field of science itself does not determine the type of normative structure that guides its researchers. The increasing specialization of the sciences and their interdisciplinary nature make any simple policy adjustments not sufficient.

In the light of our findings, we argue that sociologists of science should reconsider the concept of scientific ethos by implementing the "non-ethos" or "opportunistic adaptation" as an important analytical tool for further theoretical and empirical research. Future investigations could identify qualities of academics who share a common ethos of science, study the pace of ethos change, or the degree to which changes link with other social institutions. Such analyses would improve our understanding of the research conduct and determine the value of concepts related to the dynamics of changes in ethos. Most importantly, additional research would contribute to the development of the existing theories and new methodological approaches to evaluate science and technology policies.

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**Compliance with ethical standards**

**Conflict of interest** The authors declare that there is no conflict of interest.



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