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Barriers to and facilitators of scientific productivity: A case study from Polish technical university

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Abstract

Scientific productivity plays an essential role in the creation of innovation and it stimulates social and economic growth. This study aimed to identify the barriers to and facilitators of scientific productivity in engineering and technology field, as perceived from the perspective of academic managers. Along with quality approach, the study relied on semi-structured interviews with managing bodies, i.e. seven deans and deputy deans from four faculties representing scientific field of engineering and technology. A single case study of Polish technical university was analysed in accordance with Braun and Clark's six-step framework and coded in NVivo software. Findings fell into four themes: scientific publication, recognition, funding research, and collaboration. The results revealed more barriers than facilitators in terms of acceleration of and motivation for research productivity. Most of them related to human, financial, organisational, structural resources, and organizational culture. The novelty of our study lies in the insights into the middle management of universities in the scientific field of engineering and technology in light of the Positive Organisational Scholarship framework.

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Introduction

The core mission of universities (apart from education and building relations with business and society) is research (Cooper 2011; Scott 2006). Higher education institutions (HEIs) endeavour to enhance research productivity by ensuring a high quality of scientific research and accountability of research funding obtained (Aprile et al. 2020). For scholars, research productivity is an ongoing process that might have a positive impact on the university and individual performance (Edgar & Geare 2013). Thus, identification of the determinants that hinder and facilitate the improvement of scientific productivity is crucial for universities in terms of boosting their status and achieving recognition in the academic environment. The novelty of our study lies in the insights into the middle management of universities in the scientific field of engineering and technology.

Scientific Productivity

Scientific productivity might be defined in a narrow, quantity approach as the number of peer-reviewed scientific publications such as scholarly articles and conference proceedings per researchers (e.g. Teodorescu 2000). However, a more extended definition of scientific productivity, which combines quantity and quality approach, has also been the basis of research. Scientific productivity involves carrying out quality research, including publishing academic papers in reputable international journals and citing these papers, acquiring research grants or external funding, and collaborating in scientific teams (Kwiek 2018). Findings of the existing studies have confirmed that the most productive academic scholars belong to research-oriented groups involved in international activities (Kwiek 2015).

Polish higher education system has been developing very dynamically over recent years. One of the essential changes in the scholarly communication in Poland is a move into a more balanced combination of quantity and quality research evaluation of scientific units, carried out every four years. Recent policy reform, called ‘the Constitution for Science’, transformed the regulations concerning evaluation and introduced new rules for the evaluation of the quality of scientific research at the level of individual disciplines. The new system takes into account the following three groups of achievements, i.e. scientific publications and patents, economic effects of research and development works, and assessment of the impact of scientific activity on the functioning of society and economy. The new approach is similar to other international assessment systems, such as the United Kingdom’s Research Excellent Framework (Korytkowski & Kulczycki 2019). Based on the evaluation results, scientific units are assigned a category that determines the rights of the University to conduct graduate and doctoral schools, award degrees and titles in individual disciplines, and specifies the number of subsidies from the government budget.

In terms of the number of publications and the impact of field-weighted citations, Polish scientific productivity is at the average European rate (Kwiek 2019). Nevertheless, the level of international collaboration (internationally co-authored articles) has the lowest rate among other European countries (Kwiek 2020). This is an important challenge for the managing bodies of HEIs in Poland whose aim is not only to motivate the top-performers to be scientifically productive, but also to encourage those who are less productive, and, for instance, accelerate them in terms of publishing (Kwiek 2018).

Barriers to and Facilitators of Scientific Productivity

Some factors facilitate while others inhibit scientific productivity. Such factors can be analysed from the perspective of institutions and countries as well as from the point of view of researchers. The results of the existing studies have demonstrated that the main institutional barriers include teaching overload and the need to obtain funds for research, while the facilitators include the size of an institution, technical orientation, unit type, geographical location, year of founding and traditions (Kwiek 2015; Wolszczak-Derlacz 2017). It means that large old universities with the appropriate *know-how* show greater scientific productivity. Still, for most HEIs, the biggest challenge is the balance between teaching and research.

Researchers with higher academic rank are more productive than junior scholars (Horodnic & Zait 2015). Advanced researchers are excellent mentors for the new generations that start their scientific journey. However, human resources in science are currently limited by the generation gap and by the loss of top professionals to commercial organisations. Horodnic and Zait (2015) emphasise that young scholars are more oriented toward material incentives rather than inner motivations. Thus, efficient contingent rewards systems are needed to attract valuable personnel (Aguinis et al. 2013; Kyvik & Aksens 2015).

Financial and organisational resources create basic conditions for scientific productivity. For example, modern scientific tools and equipment are necessary to conduct research (Gaughan et al. 2018; Tartari et al. 2018). Structural resources are helpful for collaboration and interdisciplinary research, including research conducted in partnership with business (Abramo et al. 2017; Landry et al. 1996). Moreover, flexible organizational structures facilitate research project management and also the establishment of new teams and networks (Perkmann et al. 2013). In addition, organizational climate, number of faculty members holding PhD, and uninterrupted time for conducting research activity, significantly accelerate scientific productivity (Smeby & Try 2005). Autonomy in research activities as well as decentralised management are also beneficial. Thus, countries with diffusion-oriented research systems are more supportive of internationalisation than those with centralised research systems (Graf & Kalthaus 2018).

Moreover, innovative performance is related to international knowledge networks. Previous research has shown that both national and international collaboration increases productivity (e.g. Luukkonen et al. 1992; Kwiek 2015). Still, scientific cooperation at the international level is a time-consuming and, to a wide extent, an absorbing endeavour (Bojko et al. 2020). The size and composition of scientific networks also have an impact on scientific productivity as solid and considerable networks award greater benefits (Gaughan et al. 2018) and scientific units that are managed cooperatively may contribute to increasing research productivity (Ramsden 1994). Knowledge is also strengthened as academics move towards better-endowed institutions (Tartari et al. 2018). Organizational culture makes scholars more aware of the organizational goals and allows them to contribute to and be involved.

In summary, barriers and facilitators derive from institutional and individual factors that should be both balanced and mutually reinforcing. In line with the Positive Organisational Scholarship (Cameron 2017), positive amplification is a recipe for a positive change and at the same time, the positive approach can also result from earlier problems, difficulties, challenges and loss. Taking into consideration these premises, both the barriers and facilitators related to scientific productivity need to be simultaneously recognised.

Research Objectives and Methods

This original research aimed to identify and describe barriers to and facilitators of increasing scientific productivity in a view of academic managers within HEI, including deans and deputy deans. Two research questions have been formulated:

Q1. What are the main barriers to increasing scientific productivity in the field of engineering and technology from the perspective of academic managers?
Q2. What are the main facilitators of increasing scientific productivity in the field of engineering and technology from the perspective of academic managers?

To better understand the complexities of the barriers to and facilitators of increasing scientific productivity, we used a qualitative method (Creswell 2009). We resolved to use a case study method as a detailed examination of a single subject, event, setting or depository of documents (Yin 2003). Based on the interpretation that case study could stand by itself without comparison to other references, semi-structured interviews were chosen as the qualitative component to ensure flexibility in discussing emerging issues and encourage a more detailed description of the investigated problem. The study was conducted at one of Poland’s technical universities with nine faculties (six faculties represent the field of engineering and technology sciences). Managing bodies, i.e. seven deans and deputy deans from four faculties representing six leading scientific fields of engineering and technology (Table 1), were invited to the interview. Deans are regarded as middle-level executive positions and central administrators in charge of a faculty within the university. They could be described as strategists and tacticians that have responsibilities to the board on the matters of the scientific and teaching program as well as planning and implementation (Boyko & Jones 2010).

Table 1. The faculty and participant characteristics

Faculty	Main Disciplines at the Faculty*	Respondents' position	Code
1	Civil engineering / Environmental engineering	Dean and Deputy Dean	A1, A2
2	Electronic engineering / Information engineering	Dean and Deputy Dean	A5, A7
3	Electrical engineering	Deputy Dean	A6
4	Mechanical engineering	Dean and Deputy Dean	A3, A4

Note. * Scientific disciplines in line with the Organisation for Economic Co-operation and Development (OECD) Fields of Science and Technology Classification

Subsequently, we applied a thematic analysis which is widely used in qualitative research for analysing data (Creswell 2009). The main goal of thematic analysis is to identify the themes or patterns that are most important for the study. We our thematic analysis in a deductive way, in which we divided data and linked various aspects of data to different themes. According to Braun and Clarke (2006), the six steps for preparing thematic analysis are as follows: familiarising oneself with the data, generating initial codes, searching for the themes, involved reviewing the themes, defining and naming themes and producing a report. NViVo software for coding and analysis of data was applied. Two main categories of barriers and facilitators of scientific productivity were used as the initial codes that were later divided into four themes to present our research results: theme 1 (publications), theme 2 (recognition), theme 3 (collaborations), and theme 4 (funds).

Results

Barriers to scientific productivity

Theme 1 revolved around the number and quality of peer-reviewed publications in valuable scientific journals. Repeated rejections and failures in terms of article publishing were identified as the main barrier within the publication theme. A1 stressed: *"The repeated failure to publish articles in high-scoring journals is discouraging. Many people come back and say: it will not work; nobody takes it (…); it is a clique, and I do not have any friends there…(…); I do not want to try anymore"*. The frequency of such situations creates an important mental barrier and undermines credibility among researchers. The interviewees also highlighted that it is very hard to achieve a "breakthrough", even with very good publications. The next barrier is the "scoring system" (a specific national system of evaluation of publications), which reflects, for example, the extension of academic contracts. Researchers who fail to deliver a required number of scored publications might struggle to renew their contracts or even be transferred to teaching positions. Besides, the respondents mentioned expensive conference fees, the small number of high-impact factor journals and ineffective publishing in most influential journals. To summarise, the common factor apart from engineering and technology disciplines in terms of publication barriers was inefficiency in being published that was contingent upon mental and financial hindrances.

Theme 2 focused on reputation and recognition in professional life that can be contributed by several factors, such as the number of citations, the Hirsch index or membership in scientific committees. The main barrier to gaining recognition was the inability to publish an article in a high impact journal, especially in the case of new researchers who are only beginning to build their reputation. Some interviewees (A5 and A7) highlighted the difficulty in achieving professional recognition without a proper scientific workshop and appropriate scientific skills. Also, prestige is based on the membership in scientific committees that invite scientists with significant achievements. A6 pointed out: "*The perception of scientists is also created by an external environment. This is, for example, the selection of individual researchers to serve as members of the Polish Academy of Science*". Another barrier was a lack of knowledge regarding scientific culture at the best universities around the world. A1 stressed: *"Researchers do not know the scientific environment at the most prestigious universities which are focused on innovations. So, in their opinion, the article is not a goal in itself…"*. Furthermore, respondents see another barrier in high fees for open access publications. In a world in which citations are the new currency, open access papers help scholars gain recognition. Thus, in terms of recognition, in the disciplines of engineering and technology, lack of knowledge of scientific culture, insufficient competencies of young researchers and financial hindrances were reported.

Theme 3 concerned collaboration among scientists which is important for scientific productivity because complex projects need teams with different competencies and resources. The barriers were centred around the methods used in the research process. Research usually takes a long time and requires proper equipment and tools that are expensive and difficult to acquire. The need to purchase appropriate equipment to conduct highly advanced research clashes against insufficient financial sources. Other obstacles were related to the inability to manage teams and the project by project managers. Some of them are overwhelmed by grant management activities and procedures. As A4 claimed, "*There is a risk that the proposed changes will not be implemented and will remain a mere theoretical framework*". Thus, in the engineering and technology disciplines, lack of funding for technical equipment and tools, poor work organization and insufficient team management skills were considered the biggest barrier to scientific productivity with regard to scientific collaboration.

Theme 4 concerned the acquisition of funds. To strengthen scientific productivity, researchers must focus on applying for grants or, depending on the discipline, patenting inventions. The main barriers to obtaining funds were associated with an ineffective model of work organisation. For example, at the beginning of the grant application process, researchers encounter problems at the administrative level. Another problem mentioned was a scientific cycle that requires talented and highly specialised staff. Due to the generation gap and rather low salaries at Polish universities, professionals are often employed by the business sector and lack the time or opportunity to work on scientific projects. Some respondents (e.g. A4) indicated that academics had numerous difficulties in gaining funds for research because experiments are very expensive and the grants obtained are not sufficient to cover all expenditures. The next barrier is a lack of publications and citations in high impact journals, which are required for grant competitions. According to A4, "*If someone does not have an impressive bibliometric indicator, then, frankly speaking, there is no chance to get funds for research. (…) In the majority of grant contests, the scientific publication background and recognition of the leader in the basic evaluation criterion and an indicator of success*". In the current competitive academic milieu, interviewees drew attention to the barriers posed by difficulties in getting funds from the industry. To some extent, this might be linked to scientific and business discrepancies in terms of project objectives. Business wants to focus only on profit, however, such an objective is unacceptable in the scientific community. To conclude, in terms of acquiring funds in engineering and technology field human, organizational and financial barriers as well as cooperation with business and industry were identified as barriers.

Facilitators of scientific productivity

Despite numerous obstacles to increasing scientific productivity, the interviewees also identified several facilitators. Theme 1 focused on managerial practices that facilitate an increasing number of publications in the engineering and technology disciplines. Firstly, article translation and proofreading can be refunded. It is supportive for non-native English speakers. Researchers who publish in open access journals can count on additional surcharge payments to cover the article processing charges. Moreover, researchers who succeed in publishing in the most influential journals can receive monetary rewards from their faculties. As A7 claimed: "*I pay extra. When a young researcher comes to me and says that his publication is accepted but he has to pay… that's fifty-fifty. Department needs to pay half, and I will pay half as well*". Furthermore, suitable assistance is assured in terms of patenting inventions. Thus, in the engineering and technology disciplines, support for additional services such as proofreading and monetary rewarding were the most popular facilitators for scientific publication.

Theme 2 concerned recognition by providing compelling metrics. The interviewees stressed that the most significant facilitator was financial support. Funds could be used for open access fees or the attendance at scientific events. Some respondents also introduced progressive evaluation systems based on publication points and records. Such systems help to monitor scientific achievements and support the career path planning: "*So, we simply define at what point the employee is, and after that, let's say, possible tips are prepared. We inform them, for example, that they should speed up in certain activities, and we highlight those activities to them…*" (A6). In sum, the practices related to financial resources and human resources were indicated as the most useful facilitators in terms of gaining recognition.

Theme 3 revolved around collaboration among researchers, scientific teams and institutions, that is one of the features common for all scientific disciplines. Respondents indicated that their main facilities for academics included openness to interdisciplinary collaboration and a lack of restrictions when it comes to establishing scientific teams. For example, A1 highlighted: "*We explicitly support the creation of research teams of various sizes. I am trying to convince adjuncts who recently got their PhD to treat themselves like they would be treated in the United States: like assistant professors. As an assistant professor, you are responsible for all programs you have implemented and for what you want to do in the future*". The interviews pointed out that interdisciplinary cooperation is crucial for complicated and extensive research at the national and international level. It was supported by A3: "*Later, they build scientific teams to solve various problems, so they know that somewhere there is someone who is doing similar research, and then we can make such contact, and this has a positive impact*". Furthermore, to succeed in this area, interviewees argued, additional financial support is necessary. Specifically, funding for the attendance in conferences, seminars or workshops was one of the facilitators of productivity. In sum, all interviewees agreed that financial resources, autonomy and openness to interdisciplinary collaboration are important.

Theme 4 alluded to several factors in our study of possible facilitators for obtaining funds. Some respondents (A1 and A2) stressed that scholars can apply for one or two years of dean's grants that could help them in their scientific career. Those grants can be spent on personal development to support the earning of research grants in the future. Other interviewees (A3 and A4) also mentioned statutory subsidies that scholars can also receive to support their research. Other respondents (A5, A6, and A7) stressed that every project that requires additional funding not covered by grants to be completed will obtain financial support. In sum, faculties' managers indicated that financial and structural resources help acquire funds. Another noticeable facilitator is an increasingly flexible administrative structure and supportive administrative units. The interviewees highlighted: "*We have set up an office to support projects. Admittedly, this is just a beginning (…), and I think, in the future, we will develop the structure and additional services offered by this office to contribute successfully, [offering] essential help during the writing process, as well as during implementations and the managing process*" (A2). In the absence of such an office, employees can use the relevant central office to acquire funds.

Discussion

In summary, the results of this study demonstrate that scientific productivity centres on four main themes that define the main academic activities: research publications, recognition, collaboration and funding. As shown on the example of the Polish technical university, the critical factors enhancing scientific productivity are human, financial, organisational, structural resources and organizational culture. From the perspective of management bodies, the key challenges in achieving scientific productivity are scholars' attitude and capabilities to perform research as well as the organisation and provision of appropriate resources. Our findings reveal that there are more barriers than facilitators in terms of increasing scientific productivity. The identified facilitators are mainly associated with financial, organisational and structural support, while the barriers are related to human resources financial, organisational and structural hindrances that restrict scientific productivity in engineering and technology research. Thus, only coherent actions that comprehensively address publications, recognition, collaboration and funding activities may bring measurable and noticeable effects in terms of scientific productivity. The barriers to and facilitators of scientific productivity from the perspective of middle-level managers are presented in Table 2.

Table 2. Barriers to and facilitators of scientific productivity – summary of findings.

Resources	Barriers	Facilitators
Human	• Scientific skills • Gaining and maintaining talented personnel • Mental attitude to coping with defeat • Work under pressure to publish scientific findings • Individual recognition	• Support for competencies development • Monetary esteem • Openness to interdisciplinary research
Financial	• Expensive conference fee, APC in Open Access journals • Cost of conducting research	• Funding APC in Open Access journals • Internal funding: grants and additional subsidies for grants awarded
Organizational and structural	• Work organization • Leadership and team management • Teaching overload • Equipment and tools • Red tape	• Flexible organizational structure • Administrative support
Culture	• Scientific culture • Know-how and scholarly communication practices • Collaboration with business and industry	• Organizational openness to interdisciplinary research • Human resources practices

The results of our study demonstrate that human resources are important hindrances in the pursuit of research productivity. Mental barriers (e.g. coping with repeated failures due to rejection of the paper) can be reduced through training, mentoring and engaging leadership on the level of a team, unit and faculty. When dealing with scientific productivity at the individual level, it is vital to analyse psychological factors, such as the ability to set goals, emotions, and the ability to cope with failure (Araújo et al. 2017). However, due to the generation gap and competitive conditions offered by commercial organisations, it is becoming more and more difficult to attract and retain talented employees. Kyvik and Aksens (2015) highlighted that the new generation of academics is better qualified, more collaborative, better funded, supported by better research conditions and supported by contingent rewards systems. Thus, young scholars are more oriented toward material incentives rather than intrinsic motivation and the need for recognition within the scientific community (Horodnic & Zait 2015). It is, therefore, no surprise that monetary rewards or cash-peer-publication reward policies for highlighted papers published in recognised reference databases are commonly applied (Aguinis et al. 2013).

Financial barriers affect the process of scientific productivity directly and indirectly. There are proofreading costs, expensive conference fees and article processing charges for open access journals. However, financial resources support the scientific skills of scholars and their development. On the input side, some financial and organizational resources, tools and equipment are needed (Gaughan et al. 2018; Tartari et al. 2018). On the output side, universities can thrive through the circulation of ideas and learning (Bikard et al. 2015). There is a specific balance of costs and gains for both parties, scholars and academics managers.

Structural resources are important for establishing new teams and organising interdisciplinary research. Flexible structures are necessary for leaders to support and manage their teams. Managers can adapt organisational structures to involve new teams and ideas and to decide how scholars should divide time between teaching and research (Perkmann et al. 2013). Moreover, modern and efficient leadership is also needed. Engaging leaders can use enthusiasm to inspire workers to follow their plans and visions, strengthen by delegating responsibility and challenging tasks, empower by learning and sharing knowledge and, finally, connect by supporting collaboration among team members (Schaufeli 2015).

International collaboration supports the exchange of mental and technological resources; however, there are costs of coordination and allocation among individuals. International networks can enhance creative ideas and innovative knowledge, especially in better-endowed HEIs with strong scientific culture and traditions (Kwiek 2015; Wolszczak-Derlacz 2017). Thus, they contribute to an increase in scientific productivity. Individual talents and competencies are located in scientific teams and build recognition for institutions and countries, while academic managers create conditions and provide resources for innovative ideas. Thus, a reciprocal effect exists between scholars' needs and institutional resources.

Our study has some shortcomings. We conducted a qualitative study in one of the biggest technical universities in Poland. The case study is based on specific institutional and regional conditions. Around the whole university structure, we engaged four from six technical and engineering faculties.

Conclusion

As members of the academic community, scientists are obligated to perform collaborative research, apply for research grants and other funding, disseminate scientific results through publications and build their own and institutional recognition within a higher education system in which these four themes are interconnected and mutually reinforcing. Our findings indicate that there are more barriers than supportive resources to scientific productivity that both focus on human, organizational, structural and financial resources and organizational culture. In line with a message from the Positive Organisational Scholarship (Cameron 2017), academic managers need to learn how to convert barriers into strengths and treat them as challenges instead of hindrances. The agenda for future research indicates that by linking the positive and negative sides, a more complex view on scientific productivity can be achieved.

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