

The Bologna reform's impacts on the scientific publication performance of Ph.D. graduates—The case of Slovenia

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Abstract

In this paper, the impact of the Bologna reform is analyzed based on differences in scientific publication performance among the Ph.D. graduates that enrolled into doctoral study programs before the implementation of the Bologna reform in Slovenia (the pre-Bologna Ph.D. graduates) and those that enrolled after (the post-Bologna Ph.D. graduates). The transition between programs was not immediate; in Slovenia, the first Ph.D. students of the Bologna doctoral study programs were enrolled in the 2005/06 academic year, while the last academic year in which it was still possible to enroll into the pre-Bologna program was 2009/10. For Slovenian Ph.D. graduates from the 2007–2016 period, their publication records from two years prior to their Ph.D. theses defense to two years after are used for the analysis. Four indicators of their scientific publication performance are analyzed and compared: productivity, collaboration, internationality, and independence – each of them capturing a different aspect of the graduates' research activities.

The results show that there is no significant difference in the average productivity and collaboration between the post-Bologna Ph.D. graduates and the pre-Bologna Ph.D. graduates, while the values for both groups in both indicators are unexpectedly notably decreasing over the years. In contrast, internationality and independence are more constant, in general, whereas the differences between the two researched groups of Ph.D. graduates are more visible. Therefore, we conclude that the Bologna reform has a significant impact on the scientific publication performance of Ph.D. graduates, as there are notable differences in the pre-Bologna and the post-Bologna Ph.D. graduates' performance.

Keywords: Bologna reform; Higher Education; Ph.D. Studies; Scientific Performance; Research Assessment.

1. Introduction

The Bologna Declaration, signed in 1999 by the higher education ministers of 29 European countries, is one of the key documents of the Bologna Process, the aim of which is to improve European higher education (HE) (Keeling 2006; Neave and Maassen 2007). Some of the declaration's goals were to create a common degree structure, to introduce a common credit system and quality assurance mechanism, and to promote the mobility of students, as well as academic and administrative personnel between institutions and countries (Deardorff et al. 2012; Van der Wende 2000).

In the first years, the Bologna Process was not given particular attention, especially in academic circles, and was accompanied by a mixture of ignorance and considerable skepticism, but before the Berlin Conference in September 2003, the Bologna Process gradually established a new European Higher Education (HE) brand (Zgaga 2004).

HE has expanded rapidly worldwide in recent decades. In particular, enrolment in HE programs increased from 68 million in 1991 to 164.5 million in 2009. In most European countries, the 2009 gross enrolment ratios in HE exceeded 50% (Crosier and Parveva 2013). The Bologna Process has to deal with this expansion, providing tools to harmonize educational programs to be comparable, compatible, and coherent. Numerous initiatives indicate the importance of the Bologna Process in reforming HE, not only in Europe but beyond (Crosier and Parveva 2013). As a result, in 2018, 48 countries were implementing the Bologna Process (Eurydice 2018).

Although the Bologna Process implied major educational reforms, none were originally directly connected to doctoral studies. The importance of doctoral education as the third cycle of HE and the first stage of researchers' career was first highlighted in the 2003 Berlin Communiqué (European University Association 2007). Specifically, it was stated that the EU economy needs the "mass" education of young researchers that are competitive with the rest of the world (Jasenek and Červeňová 2008). As a result, the Bologna Process encouraged all institutions to offer research-based HE to ensure that the research component is included and developed in all study cycles (European University Association 2007). Moreover, scientific research in Europe was also supported by the Lisbon Strategy that was devised in the year 2000 by the European Commission. It emphasized the significance of research for economic growth and employment and, therefore, made a positive impact on research activities in Europe (Keeling 2006).

Our research goal is thus to discover how successful Slovenia is in terms of implementing the Bologna reform's and the Lisbon Strategy's aims in the third study cycle. We will attempt to reach this goal by analyzing the differences in the scientific publication performance of the Ph.D. graduates that enrolled in doctoral programs before the implementation of the Bologna reform (hereafter: pre-Bologna Ph.D. graduates) and the ones that enrolled after (hereafter: post-Bologna Ph.D. graduates). Here, we note that the transition between the pre-Bologna and post-Bologna doctoral study programs was not immediate. While it was possible to enroll in some post-Bologna doctoral study programs in the 2005/06 academic year, some of the pre-Bologna programs allowed

enrollment until the 2009/10 academic year. For that reason, we were able not only to compare the two groups of Ph.D. graduates overall but also within several particular years of our analysis period. The main part of our paper is thus answering the following research question.

What are the differences in scientific publication performance among pre-Bologna and post-Bologna Ph.D. graduates in the period between 2007 and 2016?

Based on the research question, we set four research hypotheses, each of them focusing on a different aspect of the scientific publication performance of Ph.D. graduates.

(H1) The scientific productivity of the post-Bologna Ph.D. graduates compared to the pre-Bologna Ph.D. graduates is significantly lower.

Since the structure of HE has non-negligibly changed due to the Bologna Process, it can be assumed that graduates have different competencies backgrounds than before (Melin and Janson 2006); for example, it is possible that, due to a shorter study duration, the research pre-knowledge of Ph.D. students is lower after the introduction of Bologna (cf. Kurelic and Rodin 2012). Specifically, before the reform, it was only possible to enroll in Ph.D. study programs after finishing a two-year Master of Science program and a four-year first cycle academic study program, while after the introduction of the Bologna reform, it is possible to enroll after finishing a two-year professional master's program and only a three-year first cycle professional or academic study program. This could result in a decreased ability to produce scientific publications and, for this reason, we expect the data will show a significant difference in the outcome of scientific productivity by the post-Bologna Ph.D. graduates compared to the pre-Bologna Ph.D. graduates, although the intention of the reform is to increase research activities at all study levels.

(H2) The Bologna reform stimulated an increase in the rate of foreign co-authors among Ph.D. graduates' collaborators.

Due to the envisaged promotion of the mobility of students and academics between institutions and countries within the Bologna reform, we expect our data will show an increase in the rate of foreign researchers collaborating with Ph.D. graduates; specifically, the relative number of foreign co-authors should be higher for the post-Bologna Ph.D. graduates.

(H3) The independence of post-Bologna Ph.D. graduates is lower compared to the pre-Bologna Ph.D. graduates.

In addition to the previously mentioned possibility of lower research pre-knowledge of the post-Bologna Ph.D. graduates, the duration of Ph.D. study programs also changed. While they usually lasted four years for the pre-Bologna Ph.D. graduates, the length of doctoral studies for the post-Bologna Ph.D. graduates is only three years (with some exceptions). We expect that this considerable difference will have an additional impact on the independence of post-Bologna Ph.D. graduates: specifically, their ability to engage in research independently from their supervisors in the first years of their careers.

(H4) The collaboration activity, in terms of the number of distinct co-authors, is higher for the post-Bologna Ph.D. graduates compared to the pre-Bologna Ph.D. graduates.

Collaboration activity is influenced by many factors, but we believe that the post-Bologna Ph.D. graduates have more collaborators due to two main reasons: the first is linked to the Bologna Process and its promotion of researchers' mobility, and the second is a general consequence of technology development, which enables the globalization of science, via the increased communication and connectedness of scientists. It became a typical practice that scientists from different institutions and countries, collaboratively work on common research projects; also, national and transnational (co-)financing is provided for scientific research collaboration activities.

The present paper is structured in the following way. In Section 2, a short theoretical framework about the indicators for our analysis is presented. In Section 3, Slovenia's HE system after the implementation of the Bologna reform is described, and the distinct features of Ph.D. studies in Slovenia are given particular attention. Section 4 describes the methodology and data used, and Section 5 presents research results. In Section 6, key findings are given, and related theories are reviewed. Finally, in Section 7, the findings are briefly summarized, and the limitations of the research and the possibilities for further research on this topic are discussed.

2. Literature review on methodology

In this paper, the focus is on researchers at the beginnings of their careers. Two groups of Ph.D. graduates are compared by using their scientific publication records as the basis of analyses. There are various ways to evaluate how well scientists perform (see, e.g., Wildgaard et al. (2014), Schmoch et al. (2010)), but the list of their publications together with the citation records remain the primary source for most of the indicators that are widely accepted among the decision-makers; focusing on publication and citation records results in a generally

observed reduction in quality of research papers (Gevers 2014); however, it is possible to develop various indicators allowing comprehensive analyses of scientists' performance using well-structured publication datasets (such as Scopus¹ or Web of Science²).

Because only the first five career years of each researcher are considered in the present paper, we limit ourselves to the researcher's scientific publications, ignoring the citation records. With the publication data of each of the researchers, four essentially different aspects of their research are investigated: specifically, how productive they are, what the intensity of their collaboration is, what their level of cooperation with foreign researchers is, and finally, how independent they are in their research. The main motivation to use the selected indicators came from two earlier works on the scientific performance of Slovenian researchers and the researchers leading research projects in part of their careers, specifically, the studies by Kastrin et al. (2017) and Kastrin et al. (2018), respectively.

The productivity in terms of the number of publications that researchers co-author can be substantially different for different researchers, as shown by Lotka (1926). However, simply counting the publications blurs the overall picture; for example, in some fields, publications are coauthored by all the researchers in a research consortium (which can mean hundreds of coauthors), while in some fields, it is typical that there are only a few coauthors, which results in smaller numbers of co-authored publications. Thus, additional indicators have been introduced in the literature, for example, only considering a relative contribution of an author (Lee and Bozeman 2005, Kastrin et al. 2017). Productivity is also strongly correlated with the collaborators, with their number (Lee and Bozeman 2005), and their success (Pravdić and Oluić-Vuković 1986). However, the correlation between the number of publications and the number of collaborators decreases as soon as one uses the relative contribution of an author (Lee and Bozeman 2005), meaning that the aspect of collaboration activities should be studied separately in such cases.

The usual approach to analyze collaboration activities is by considering the co-authorship networks. In this area, Newman's works are considered fundamental (see, e.g., Newman 2004). For the case of Slovenia, co-authorship networks of researchers have been thoroughly investigated by Perc (2010a) and Kastrin et al. (2017). Examining co-authorship networks reveals various interesting properties. Lužar et al. (2014) studied the dynamics of interdisciplinary research within research communities and found that it is proportional to the growth of the entire network. Yoshikane and Kageura (2004) investigated differences in the characteristics of co-authorship networks between scientific domains. In co-authorship networks, the main impact on the scientific performance of individual researchers was on their direct collaborators (i.e., their ego-network) and their position in the network (Abbasi, Chung, and Hossain 2012). Perc (2010b) also used citation data information and, based on that, proved that the distributions of citations per publication for various research fields and scientific institutions in Slovenia follow Zipf's law.

The structure of the data used for the research in the present paper also enables distinguishing the foreign collaborators of researchers, thereby addressing the third aspect: internationality. At the beginning of the millennium, Glänzel (2001) observed that international collaboration was growing and that new communication technologies additionally accelerated this growth. Also, the internationality of authors is correlated with the number of a publication's citations (Glänzel and Schubert 2005, Narin et al. 1991).

The fourth aspect of scientific performance analyzed in the present paper is how successful researchers are in conducting their research independently of their supervisors. The aim of Ph.D. education is to convert a Ph.D. student into a critical and independent researcher, but many students are nonetheless expecting the full support of their supervisors (Ndanguza and Mutarutinya 2017). An indicator covering this aspect has recently been addressed by Van den Besselaar and Sandström (2019).

Clearly, as in the first three indicators, one must have in mind that low or high values of one indicator may not indicate the excellence or inability of a researcher. In this sense, considering the first three indicators, researchers working with their supervisors throughout their careers can receive high values, and those working completely independently can receive low values. Therefore, the scientific productivity of each researcher should be carefully evaluated from different perspectives, including that of independence.

3. Impacts of the Bologna reform on Slovenian HE

3.1. Slovenian HE system after the introduction of the Bologna reform

Slovenia joined the Bologna reform in 1999, while wider interest in the Bologna Process started after 2002, similar to the rest of Europe. As a result, a three-cycle Bologna study structure was introduced in 2004 (Zgaga 2004).

The Bologna Process was started with an awareness of the previously identified problems, obstacles, and paradoxes of HE along with internationalization. There were many dilemmas and controversies about the

¹ <http://www.scopus.com>

² <http://www.webofknowledge.com>

interpretation of the Bologna idea, for example, how to translate previous programs into the new three-cycle Bologna system (Zgaga 2004).

Slovenia is not among the best-ranked countries in terms of HE indicators. For example, Slovenia had the longest average length of studies among OECD³ countries (OECD 2017) in 2015, with 5.7 years in terms of the average difference of age of graduates when finishing the first level of their studies and their age when enrolling in the studies for the first time, while EU21 average was 3.5 years. This raises a question: in which ways are Slovenian studies different in terms of quality from studies in other countries?

The notion of quality in teaching and learning has evolved in the attempt to establish a European HE area, especially in the context of the Bologna Process (Kehm 2010). For this reason, Slovenia established an independent National Agency for the Quality of Higher Education (NAKVIS) in 2010. Since 2015, it has been a full member of the European Quality Assurance Association for Higher Education. NAKVIS is responsible for quality assurance in HE, and for the development and advisory work in this field, while it also grants accreditations to HE institutions and their study programs.

At the end of 2018, there were three public universities in Slovenia, an independent public HE institution, three private universities, and 41 independent private HE institutions. There were 945 accredited study programs provided by 106 accredited HE institutions: 50 of which were public institutions, and 56 were private institutions. Regarding the doctoral programs, there were 104 study programs provided by 55 HE institutions, 19 of them private and 36 public.⁴ A comparison of the number of HE institutions (HEI) and their study programs with the Slovenian population (2.070 million inhabitants in Slovenia in the second half of 2018⁵) shows there were 19,529 inhabitants per HEI and 2,191 inhabitants per accredited study program. Excluding the population aged 0-18 and 65+ years, which together comprise more than 38% of the population, there were 12,046 inhabitants per HEI and 1,351 inhabitants per accredited study program, which is a significant indicator of the current fragmentation and diversity of the Slovenian HE system.

Also, with 74% of its population aged 20–34 included in the education processes, Slovenia is ranked first in 2017 among OECD countries; the EU22 average was 57% (OECD 2018). All this shows that the Slovenian HE system has changed significantly in recent decades and has become unique in terms of several aspects that require special attention.

3.2. Specific features of Ph.D. studies and the situation in Slovenia

Doctoral research is traditionally primarily carried out for academic purposes and therefore has little impact on national competitiveness in general. Knowledge transfer to society and enterprises is scarce, largely because the productive sector itself usually does not actively support academic research and development. This results in weak national innovation systems, which is precisely the opposite of what is needed in a knowledge-based society (Deardorff et al. 2012).

For this reason, doctoral studies have become a focus of increasing attention from policymakers. The intention of policymakers and universities was to evolve third missions in addition to the two established key missions of research and teaching and to commercialize academic knowledge. For instance, evolving it through ongoing education programs, science parks or incubators, technology transfer offices, and patenting has raised the relevance of industry-university cooperation (Marhl and Pausits 2011; Perkmann et al. 2013; Rybnicek and Königsgruber 2019).

At the same time, the efficacy and relevance of doctoral training are being reviewed for their nonacademic employment. The newly arisen attention to transferable research expertise training, which can be observed in Finland, Germany, Norway, Switzerland, France, and Belgium, may well be observed as an indirect result of the Bologna reform (Reichert 2010). Furthermore, in Slovenia, there is an increasing number of Ph.D. students that come from outside of academia and focus on research with not only scientific contributions but also transferable practical implications. For instance, in the previous decade, several public calls aimed to increase the collaboration between HE and industry (e.g. the so-called “Young researchers from the industry”)⁶.

Another trend involves support for new interdisciplinary centers or doctoral programs within and between institutions, especially in Germany, France, Switzerland, the Netherlands, and Scandinavian countries (Reichert 2010), while in Slovenia, interdisciplinary research is receiving only limited governmental attention and, consequently, limited financing. In 2017 (ARRS 2017) and 2018 (ARRS 2018), interdisciplinary research activities were not financed by the Slovenian Research Agency for the Young Researchers public tender, although it was financed for other research programs. By “young researchers,” we mean special financing by the

³ Organisation for Economic Co-operation and Development currently has 36-member countries, from North and South America to Europe and Asia-Pacific, including 27 from the Europe (<https://www.oecd.org/about/members-and-partners/>) which are also among European Higher Education Area (EHEA) countries. EHEA / BFUG (Bologna Follow-up Group) members are 48 countries and the European Commission (http://eha.info/page-full_members).

⁴ https://www.nakvis.si/wp-content/uploads/natasa/Javna-evidenca-SP-akreditiranih-po-1-mar-2010_20-6-2019.xlsx

⁵ https://pxweb.stat.si/SiStatDb/pxweb/en/10_Dem_soc

⁶ Those Ph.D. students performed their research within companies, but were fully financed by the Ministry of Education, Science and Sport.

Slovenian Research Agency, which supports prospective students to enroll in doctoral programs by providing employment grants for the time of their studies. We refer to them as “AYRs,” i.e., Agency Young Researchers.⁷ Every year, the Slovenian Research Agency provides financing for a certain amount of AYRs so that they can participate in research work at faculties during their postgraduate studies. In 2017, the agency financed 842 AYRs (ARRS 2017), while it financed 899 of them in 2018 (ARRS 2018), which represented 29.8% and 29.1% of the total number of Ph.D. students enrolled in the 2017/18 and 2018/19 academic years, respectively.⁸

In Slovenia, public (co-)financing of three-year doctoral research programs can also be granted to other students, not only to AYRs. For example, from 2017 on, there is new legislation in force, the “Decree on the co-funding of doctoral studies,” which provides public (co-)financing of the tuition fee, but only at public institutions. Based on it, public HE institutions receive financial funds to decrease tuition fees of full-time Ph.D. students. Since the decrease is conditioned by several different factors, the majority of eligible students still have to pay at least a part of their tuition.

Despite most third-cycle degrees having an official duration from three to four years, most countries note that, in reality, doctoral candidates usually need more time to complete their degrees (Crosier and Parveva 2013), and this is also seen in Slovenia. The reason for this is also the fact that the objectives for doctoral studies are not determined as precisely as they are in study programs at lower levels. The standards that a Ph.D. student needs to achieve to finish a study can vary from institution to institution and even from advisor to advisor.

Therefore, the role of a qualified advisor is very important, but the study of the impact of doctoral advisors found that (a) students with greater incoming potential received more advisor mentoring, and (b) advisor mentoring did not significantly contribute to key student outcomes, including research productivity (Green and Bauer 1995). Moreover, the longitudinal study of the effect of mentorship on the research productivity, career commitment, and self-efficacy of Ph.D. students reveals that positive benefits of mentoring were found for subsequent productivity and self-efficacy, while mentoring was not significantly associated with commitment to a research career (Paglis et al. 2006).

In the cases of young researchers, the supervisor-student relationship is perhaps even more significant. This interaction is affected by the characteristics and needs of students and institutional conditions, as well as the skills, attitudes, roles of advisors, and their supervisory styles (Orellana et al. 2016).

There are also important differences between advisors’ perceptions concerning their role and students’ needs regarding supervision. They demonstrate the importance of considering students’ needs and exercising responsibility in the development of research competencies in students (Orellana et al. 2016).

In Slovenia, there were certain changes due to the transition to the Bologna system, which had an additional impact on Ph.D. studies. One such transitional situation is the possibility for pre-Bologna university programs’ graduates, who had finished a four-year study program (the 1st cycle), to directly enroll in Bologna Ph.D. studies (the 3rd cycle). This motivated many of them to enroll in the third cycle, but after a while, most of them faced problems while studying, since they had no experience nor competences from the master’s studies on how to perform scientific research.

Specifically, before the introduction of the Bologna reform in Slovenia, the enrollments into Ph.D. studies were possible after finishing four-year first cycle academic programs, followed by two years of Master of Science programs. On the other hand, candidates can now enroll in Ph.D. studies after three years of the first cycle professional study program followed by two years of the master’s professional program. Consequently, we believe that the research pre-knowledge of the post-Bologna Ph.D. students is lower. Kurelic and Rodin (2012) also argue that “the problematic quality of education at the master’s level and the lack of meaningful selection lead to competences that are inadequate for doctoral research. Master’s students are not qualified to pursue doctoral research, and the missing competences have to be compensated for during doctoral studies, which, in turn, leads to longer periods of studies at the doctoral level.”

The reason for the above-mentioned problematic indicator can also be found in the fact that students often enter a doctoral program with a low “hands-on” understanding of the demands of such programs. They then find themselves in a situation that bears little resemblance to the previous degree programs they had successfully completed, especially since the introduction of the Bologna reform. Therefore, although students are generally highly motivated, a crucial component for their success is the ability to handle the program and manage different stages of challenges that can be harmful to success (Grover 2007).

4. Data and methodology

⁷ The Agency finances their salaries, social contributions, as well as material and non-material costs. Funds for the training of AYRs are allocated for a fixed-term, up to a maximum of 4 years (duration of Ph.D. studies - 3 years plus 1 additional year).

⁸ <https://www.stat.si/StatWeb/Field/Index/9>

In this paper, the scientific publication performance of researchers that defended their doctoral theses in the years from 2007 to 2016 are analyzed, using their publication records from two years prior to two years after the Ph.D. theses defenses, hence using the publication data from 2005 to 2018. This period was chosen so that the behavior of individual researchers would be similar but still show the differences between the activities before and after the doctoral studies implemented the Bologna reform. We stop in 2016 so that we can monitor scientific publication performance two years after the defenses of theses for all researchers in the analyses.

The data were obtained from a national information system, the Cooperative Online Bibliographic System & Services (COBISS). The COBISS system contains publication records, which in the case of scientists mainly includes, but is not limited to, scientific papers, monographs, conference contributions, and similar. Moreover, in the COBISS system, there are also records about bachelor's, master's, and doctoral theses. Due to its completeness, the COBISS system (and the accompanying SiCRIS database introduced below) has already been used for various analyses of research activities in Slovenia (see, e.g., Ferligoj et al. (2015), Karlovčec et al. (2015), Karlovčec et al. (2016), Kronegger et al. (2012), Lužar et al. (2014), Kastrin et al. (2017), Kastrin et al. (2018), and Perc (2010a)).

For the purposes of this paper, all the records about doctoral theses from COBISS that have been defended in the researched interval were collected. The authors of these theses represent the initial set of researchers to be analyzed. This set of records had to be further reduced for several reasons. Firstly, in COBISS, there are records about several doctoral theses obtained at universities outside Slovenia, and hence the authors of these are not of interest to us. Secondly, there are researchers with multiple Ph.D. titles, for which only the theses being obtained first were used. Finally, in some rare cases, there are duplicate records in the system, usually due to two recorded versions of the thesis: the physical and the electronic version. From now on, we refer to the final set of these authors as “the Ph.D. graduates.”

In what follows, the indicators that have been assigned to each researcher from the set of Ph.D. graduates are described.

- **Pre-Bologna/post-Bologna.** We determine if a Ph.D. graduate finished her/his Ph.D. studies in the pre-Bologna or the post-Bologna program. We note here that we are aware of the possibility that some Ph.D. graduates finished their undergraduate studies in pre-Bologna programs and continued Ph.D. studies in post-Bologna programs.
- **Publications.** Our analysis is based on the publication records of the observed Ph.D. graduates, in which we limit ourselves only to publications a Ph.D. graduate co-authored in the period from two years before her/his thesis was published to two years after (we denote this period simply as the “ ± 2 -period”). Altogether, we monitor the publication records of an individual in five-year intervals. Within these five years, the impact of the differences between pre-Bologna and post-Bologna programs to Ph.D. graduates' scientific publication performance should be detected. Additionally, we do not consider complete publication records but only use publications related to the scientific work of the researchers. Specifically, we collect scientific articles, review articles, short articles, conference contributions and conference abstracts, book chapters, and monographs.
- **Co-authors.** Having the publication record for each Ph.D. graduate, we also track the co-authors of each publication. In this way, we obtain a set of researchers that have, at some point, collaborated with a Ph.D. graduate (these authors are forming the Ph.D.'s ego-network).

As already mentioned, the present paper's analysis is based on the publication records of Ph.D. graduates and the data related to them (e.g., data about co-authors). Using the publication records, the four below-listed indicators of scientific publication performance were analyzed. Simplified versions of the first three indicators, productivity, collaboration, and internationality, have been introduced by Kastrin et al. (2017) as indicators to study the scientific publication performance of Slovenian researchers in the period from 1970 to 2015. Note that for productivity, the definition of the relative productivity enhanced by introducing weights for different types of publications was used (see the definition below). The fourth indicator, independence, is a simplified version of indicators introduced by Van den Besselaar and Sandström (2019), and we introduce it, since we believe it covers an aspect of research activities which is not sufficiently covered by the former three.

- **Productivity.** Measures the scientific output of Ph.D. graduates in terms of publications. For each publication of a Ph.D., we multiply her/his relative contribution (i.e., the reciprocal value of the number of the publication's authors) with the weight of the type of publication (see Table 1). The sum of all factors is the researcher's productivity. We determine the weights using a simplified model that follows the methodology used by the SiCRIS database (Slovenian Current Research Information System), which contains data about the researchers registered in Slovenia, research organizations, groups, and projects being (co-)financed by the Slovenian government.

Scientific Article	0.194363
Review Article	0.194363
Short Article	0.155491
Invited Conference Contribution	0.076531
Conference Contribution	0.076531
Invited Conference Abstract	0.006803
Conference Abstract	0.006803
Chapter	0.110544
Monograph	0.178571
Sum	1.000000

Table 1: Weights for the publication types used to compute researchers' productivity

- **Collaboration.** Measures the number of distinct collaborators of a researcher in a given interval. In this paper, collaboration is considered in terms of co-authorships. A researcher's collaboration is hence regarded as the size of her/his co-authorship ego-network. Note that we do not use the above-described weights for this and the following indicators, since none of them is conditioned by the resulting publication type.
- **Internationality.** Measures collaboration of researchers with foreign researchers. Since most of the researchers in Slovenia are registered in the SiCRIS system, we consider collaborators that are registered in it to be domestic, while the others are considered to be foreign. Internationality is the ratio between the number of foreign co-authors in the researcher's ego-network and the size of her/his ego-network.
- **Independence.** This gives insight into the Ph.D. graduate's ability to perform research independently, meaning without the advisor or even completely alone. Independence is the ratio between the number of publications a Ph.D. graduate published in the considered interval not being co-authored by any of her/his advisors, and the number of all her/his publications.

Finally, we remark that we are aware of the fact that publication culture differs within different scientific disciplines (King 2004), but in order to reduce the complexity of the presentation, we do not distinguish the analyzed Ph.D. graduates according to their research fields.

In the next section, we present computations and comparisons of the above-listed indicators for both groups of Ph.D. graduates (the pre-Bologna and the post-Bologna).

5. Results

In our analyses, we use data for all 6012 Ph.D. students that defended their Ph.D. theses in the years from 2007 to 2016 in any of the Slovenian doctoral programs. Out of these, there are 4860 pre-Bologna Ph.D. graduates and 1152 post-Bologna Ph.D. graduates, with the first post-Bologna Ph.D. title obtained in 2009. Here, we note that 82 of the observed Ph.D. graduates had no bibliographic records (i.e., publications of types we are considering) in their ± 2 -periods.

A specific situation resulting from the Bologna reform introduction that needs to be highlighted for Slovenia is a huge increase in the number of Ph.D. students after the 2005/06 academic year when the first post-Bologna Ph.D. student was enrolled. A year-on-year increase lasted until the 2011/12 academic year, following which a moderate decline in enrollment can be observed⁹.

The data also show that in the researched period (2007–2016), the number of Ph.D. graduates was constantly growing at CAGR of 8%, while the number of Ph.D. students shows growth at CAGR of 6%.

The academic year 2009/10 was the last one in which it was possible to enroll into pre-Bologna Ph.D. programs, while it was mandatory to finish all pre-Bologna studies (including Ph.D.) until the end of 2015/16, which resulted in the increase of pre-Bologna defenses of doctoral theses in 2015 and 2016 (Figure 1).

The primary purpose of this paper is the analysis of the scientific publication performance of Ph.D. graduates using their bibliographic records for the ± 2 -periods. From them, we computed four indicators of scientific publication performance: their productivity, collaboration, internationality, and independence. The analysis for each indicator is performed in two ways. In the first, we compute average values of the indicators for both groups of Ph.D. graduates, the pre-Bologna and the post-Bologna, for every year in the researched period (and also the total averages) by taking the complete publication record over the five-year intervals for Ph.D.

⁹ https://pxweb.stat.si/SiStatDb/pxweb/en/10_Dem_soc

graduates. For each year, we consider only the Ph.D. graduates that defended their Ph.D. theses in that year. By doing so, we can detect differences between the two groups within single years and also observe the trends of the indicators' average values.

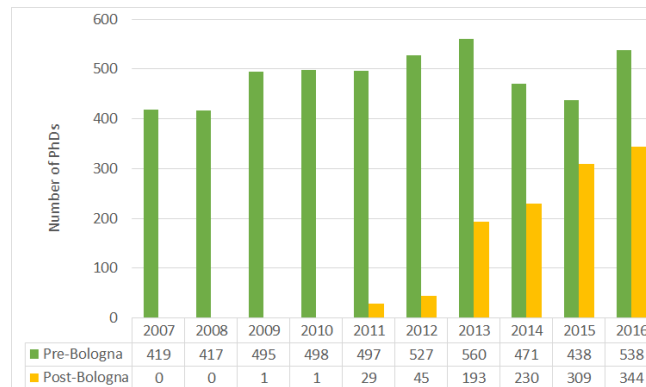


Figure 1 Number of defended pre-Bologna and post-Bologna doctoral theses in Slovenia between 2007 and 2016

The second analysis is by individual years in the ± 2 -periods. In this way, we can observe the average values in each of the five years for which we track the scientific publication performance of individual Ph.D. graduates. The results should tell us if the Ph.D. graduates perform better over the years and how they performed regarding their doctoral studies type. Since the values of some indicators are normalized, the sums over the five years (the heights of columns) in charts are not related to the values of the yearly analyses.

We also note that in the charts, the average values of indicators for the first two post-Bologna Ph.D. graduates finishing their studies in 2009 and 2010 are omitted, since their scientific research activities were in most cases rather extreme (e.g., the average collaboration of all post-Bologna Ph.D. graduates was 12.21, while theirs was 48 and 35, respectively).

5.1. Productivity

The Ph.D. graduates, both pre-Bologna and post-Bologna, who plan to work in academia, are motivated to publish as much as possible, since the requirements for obtaining a good postdoc position, or even an academic title, usually depend on their publication records. In Slovenia, it can even be better to have more publications of lower quality than to have fewer publications of higher quality. Bearing this in mind, we expect that Ph.D. graduates start publishing as soon as possible.

The results show that productivity is decreasing every year in both the pre-Bologna and the post-Bologna Ph.D. groups of graduates. From 2013 to 2016, the productivity of the post-Bologna Ph.D. graduates was higher than that of the pre-Bologna Ph.D. graduates (Figure 2); in 2015 and 2016, it was significantly higher. We believe that the reason for this is that in these years, the majority of the pre-Bologna Ph.D. graduates were comprised of students who were already studying for more than the usual four years (since the pre-Bologna programs were replaced by the post-Bologna programs). Hence, it is reasonable to assume that these students are less successful scientifically and thus have lower productivity. However, the projected constant decline of productivity for both Ph.D. groups of graduates suggests that the focus is turning to quantity (i.e., mass enrollments to doctoral studies).

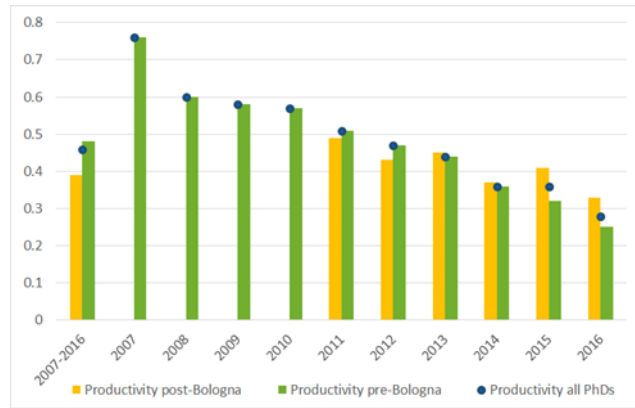


Figure 2 Average productivity of the pre-Bologna and the post-Bologna Ph.D. graduates in Slovenia between 2007 and 2016. In the first column, average productivities, regardless of the year, are presented.

In Figures 3 and 4, an interesting phenomenon can be observed: there were small differences in average productivity within each of the five years in ± 2 -periods, which is somewhat surprising as one would expect that the productivity of Ph.D. graduates in the two years before the Ph.D. defense was substantially smaller than in the subsequent years.

The productivity of the post-Bologna Ph.D. graduates was the highest in the dissertation defense year (Figure 3), which is expected, since most of the Ph.D. programs require the publication of a scientific paper before the thesis defense, and such a publication is usually realized (or at least published) in the same year as the defense.

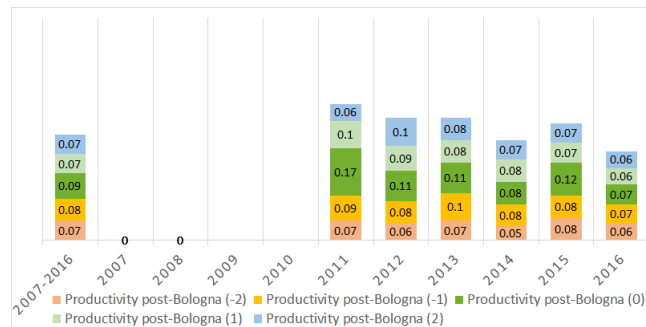


Figure 3 Average productivity of the post-Bologna Ph.D. graduates in ± 2 -periods in Slovenia between 2007 and 2016.

In contrast, data for the pre-Bologna Ph.D. graduates do not show the highest productivity in the same year as the dissertation defense until 2012 (Figure 4), but the productivity was higher in the year after the Ph.D. thesis defense, since many publishing houses offer publication of dissertation theses, and Ph.D. graduates often decide to publish their thesis as a monograph (which have high scores in our methodology). Regardless, in both research

groups (post- and pre-Bologna Ph.D. graduates), the differences in average productivities in ± 2 -periods were rather small.

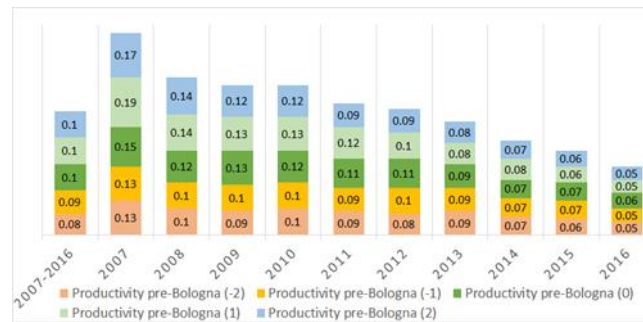


Figure 4 Average productivity of the pre-Bologna Ph.D. graduates in ± 2 -periods in Slovenia between 2007 and 2016

Since we used weights for publications and normalization to compute the productivity, we also computed the number of publications a Ph.D. graduate published, without any other modifications. The results also clearly show an alarming decline in the number of publications in both the pre-Bologna and the post-Bologna Ph.D. groups of graduates in the observed period (Figure 5). The post-Bologna Ph.D. graduates registered a smaller number of publications in total, mostly because the pre-Bologna students were much more productive in the years before 2012, while the numbers started to decrease afterward. For 2016, the results show that the average number of publications even drops below 10 for both sets of Ph.D. graduates.

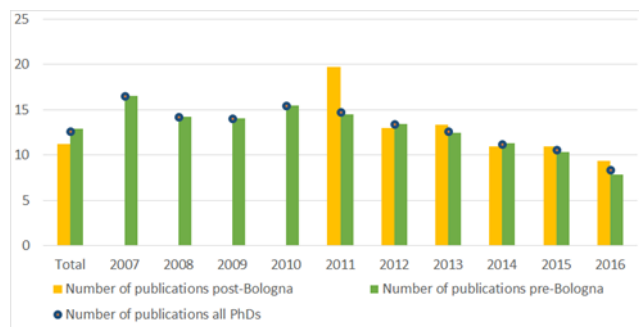


Figure 5 Average number of publications of the pre-Bologna and the post-Bologna Ph.D. graduates in Slovenia between 2007 and 2016

Figures 6 and 7 provide different insights than Figures 3 and 4. They both show variations of values in the ± 2 -periods. In addition to the declining trend of the number of publications in the researched period (2007-2016), in Figure 6, it is shown that the total number of publications in the post-Bologna Ph.D. graduates' group is growing from the year -2 until the year of the thesis defense (inclusive), and moderately declining afterward (Figure 7).

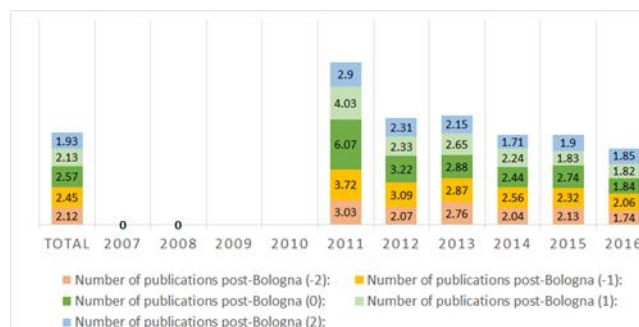


Figure 6 Average number of publications of the post-Bologna Ph.D. graduates in the ± 2 -periods between 2007 and 2016

As in the post-Bologna Ph.D. graduates' group, the pre-Bologna Ph.D. graduates also registered a growing number of publications in total in ± 2 -periods from year -2 until the year of the thesis defense, and moderately decreasing afterward.

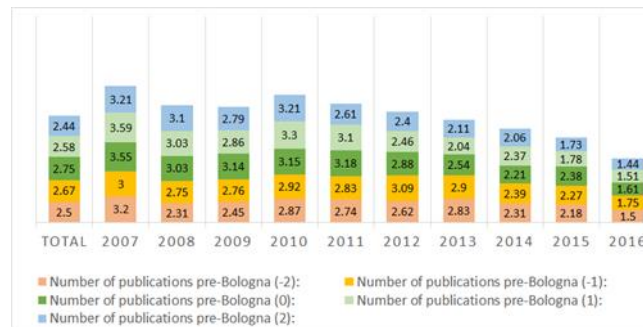


Figure 7 Average number of publications of pre-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

Very soon after a Ph.D. student publishes the required publications (as already mentioned, some more recent Ph.D. programs do not even require any scientific publication), she/he can finish Ph.D. studies, meaning that the year of the most important publications is very often the same as the year of the Ph.D. thesis defense. However, after publishing the results from the topic of the thesis, a Ph.D. graduate starts working on new research topics, and possibly even without an advisor's aid, which results in decreased ability to publish many new papers shortly after the defense. Another reason for the decline in the average number of publications in the years after their thesis is that some of the Ph.D. graduates are finding or maintaining employment in non-academic companies and organizations. In particular, in our data, there are 1664 Ph.D. graduates (out of 6012) who have no publication after the theses defense years.

5.2. Internationality

The collaboration with foreign researchers has proved to be beneficial for researchers, for a number of reasons, (c.f. Glänzel and Schubert 2005; Kastrin et al. 2017). Although it has been proven to be growing (Glänzel 2001; Kastrin et al. 2017), for the case of the Ph.D. graduates in our study, we have found that the average internationality of the pre-Bologna Ph.D. graduates is more or less constant over the years, with the lowest value in 2016 (Figure 8). This is affected by the smallest productivity in that year. In contrast, the average internationality of the post-Bologna Ph.D. graduates is varying, and its values are relatively much higher in some years than the values of the pre-Bologna Ph.D. graduates (Figure 8). This is expected, since the Bologna reform and many other EU projects stimulate international collaboration, which should result in increased collaboration of researchers with foreign colleagues. Thus, the Bologna reform brought a positive impact on doctoral studies, despite the declining trend of internationality for both groups of Ph.D. graduates.

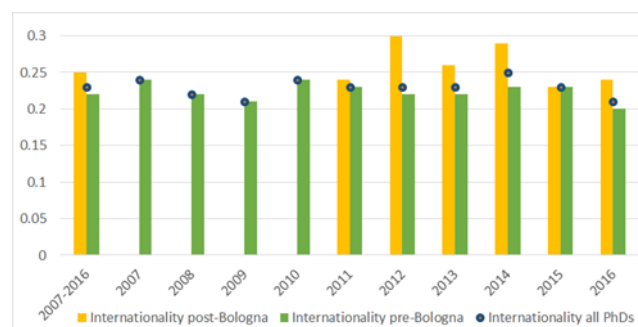


Figure 8 Average internationality of the pre-Bologna and the post-Bologna Ph.D. graduates in Slovenia between 2007 and 2016

When considering the values of the average internationality within individual years for both groups of Ph.D. graduates, one can first observe that those are much smaller than the average values over the whole ± 2 -periods. The reason for this is that collaboration with domestic colleagues (colleagues working at the same institute or even in the same office) is easier and more accessible than working with colleagues from other countries. Thus, within one year, there can be many domestic collaborations and, therefore, a small relative number of foreign co-authors (i.e., low internationality). However, when we consider the whole ± 2 -period, the domestic colleagues

are seen repeatedly in the ego-network, while the number of distinct foreign colleagues is, on average, increasing; higher internationality is the result of this.

The average internationality of the post-Bologna Ph.D. graduates in ± 2 -periods shows a decline in 2015 and 2016 (Figure 9). In most years, the year of the thesis defense shows the highest internationality, while the lowest is usually in the -2 year when the Ph.D. graduates were just starting with serious research work.

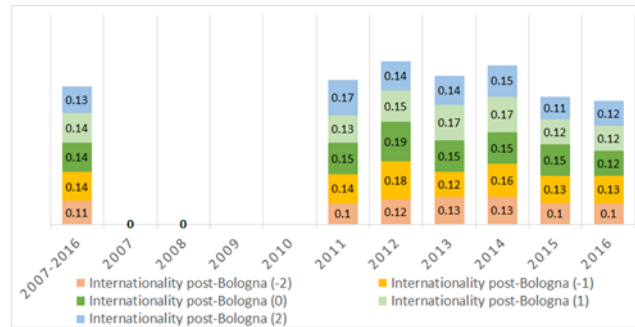


Figure 9 Average internationality of the post-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

In contrast, the average internationality of the pre-Bologna Ph.D. graduates is more dynamic in the sense that the years of the ± 2 -periods, in which the peaks are reached, vary through all possible years, except for the -2 year (Figure 10). We note here that, except for 2008, the average yearly internationality never drops below 10%, which means that foreign collaboration is always present at least to some level.

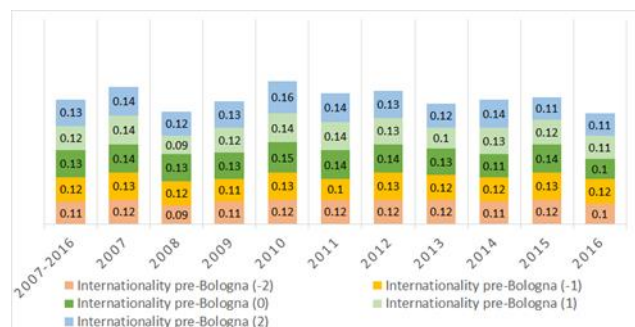


Figure 10 Average internationality of the pre-Bologna Ph.D. graduates in ± 2 -periods in Slovenia between 2007 and 2016

5.3. Independence

The initial screening of research results revealed a declining trend in independence. Figure 11 shows that, in total, the average independence declined by 17% when comparing 2007 and 2016. The considered period's CAGR, in contrast, shows an increase of 3% in the post-Bologna Ph.D. graduates' average independence, while the pre-Bologna Ph.D. graduates' CAGR declined by the same 4% as the total did. However, a closer look reveals that the decline stopped in 2013, and it stabilizes afterward.

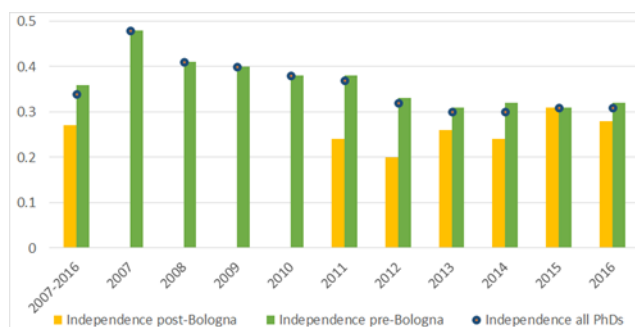


Figure 11 Average independence of the pre-Bologna and the post-Bologna Ph.D. graduates in Slovenia between 2007 and 2016

As with the total, general trends of average independence levels of the pre-Bologna Ph.D. graduates also show that the average independence was declining in the researched period until 2013 when it stabilized around 0.3. In contrast, Figure 11 clearly shows that post-Bologna Ph.D. graduates' average independence increased gradually, although its values are oscillating throughout the period. As expected, the values for pre-Bologna Ph.D. graduates are much higher until 2014, since in pre-Bologna programs' students were more capable of independent scientific work, because they were based on master's degree study programs.

It can be observed that the average independence of both the post-Bologna and the pre-Bologna Ph.D. graduates increased in the ± 2 -periods each year, which proves the evident fact that Ph.D. graduates do gain independence during their studies and after (Figures 12 and 13).

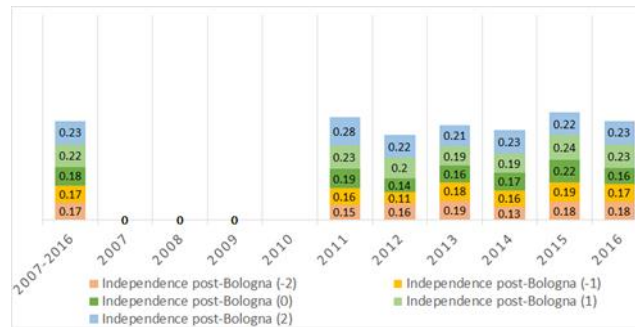


Figure 12 Average independence of the post-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

The declining trend mentioned for the yearly analyses is also visible for the pre-Bologna Ph.D. graduates when considering individual years in the ± 2 -periods. The pre-Bologna Ph.D. graduates also perform better than the post-Bologna group in the ± 2 -periods (Figures 12 and 13) in total.

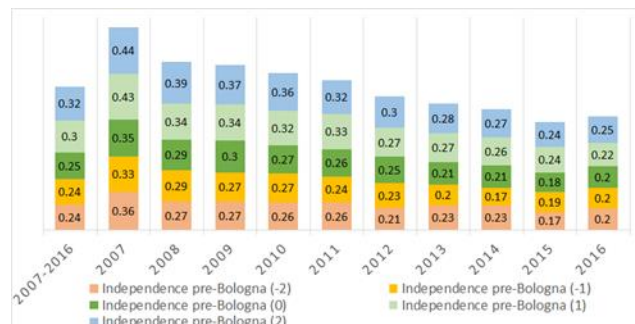


Figure 13 Average independence of the pre-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

In this subsection, apart from the average independence results, we also consider the “solo papers” indicator (Figure 14), in order to provide additional insights into the independence indicator. With the term “solo paper,” we mean a publication authored solely by a Ph.D. Figure 14 presents a clear trend of the declining average number of solo papers per Ph.D.

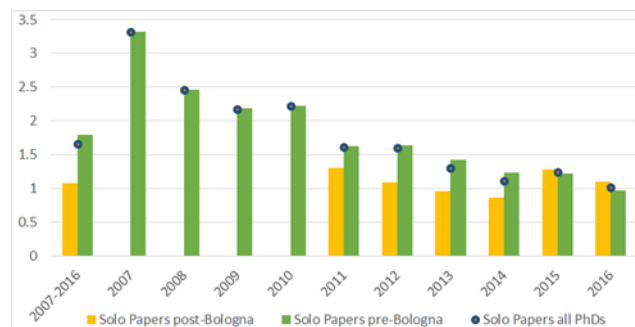


Figure 14 Average number of solo papers of the pre-Bologna and the post-Bologna Ph.D. graduates in ± 2 -periods in Slovenia between 2007 and 2016

The results also show that the post-Bologna Ph.D. graduates, on average, published fewer solo papers, which is in line with lower average independence. However, in the last two years (2015 and 2016), the post-Bologna Ph.D. graduates were better in this indicator, but not in the independence indicator.

5.4. Collaboration

No significant differences in average collaboration between the post-Bologna and the pre-Bologna Ph.D. graduates are observed, in general, although 2011 and 2012 were somewhat significant for post-Bologna Ph.D. graduates (Figure 15), since at that time there was a smaller number of Ph.D. graduates finishing their studies; however, they were more collaborative than the vast majority.

Collaboration is correlated with the number of publications. In particular, a higher number of publications increases the probability of higher collaboration. Between the average number of publications of all Ph.D. graduates and the average collaboration indicator of all Ph.D. graduates, the Pearson's coefficient (0.65) and the Spearman's coefficient (0.66) show strong positive correlation in the researched period (2007–2016). A calculation of R-Squared indicates that 42.25% of the variance in the number of publications is explained by the variance of the collaboration indicator.

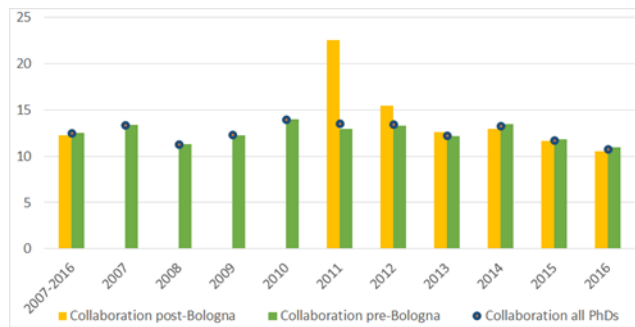


Figure 15 Average collaboration of the pre-Bologna and the post-Bologna Ph.D. graduates in Slovenia between 2007 and 2016

Since the average number of publications for both the post-Bologna and the pre-Bologna Ph.D. graduates decreased over the researched years, it is expected that this trend in collaboration would also be detected. However, a decreasing trend in average collaboration is clearly visible only for the post-Bologna Ph.D. graduates, while the decrease for the pre-Bologna group is shown only from 2014 onward (Figure 15).

Similar to the average number of publications, the collaboration of the post-Bologna and the pre-Bologna Ph.D. graduates was the highest in the same year as their Ph.D. theses defenses (Figures 16 and 17). One can observe that for post-Bologna Ph.D. graduates, the values for every single year in the ± 2 -periods are decreasing over the period from 2011 to 2016 (with some minor exceptions).

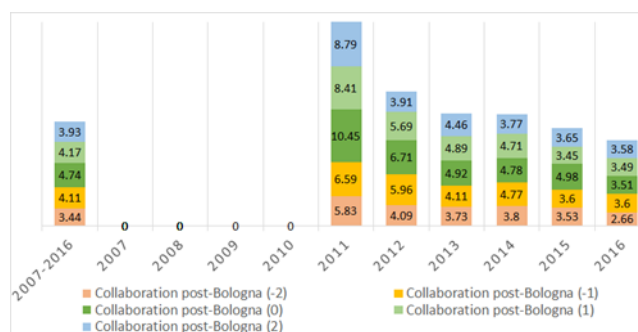


Figure 16 Average collaboration of the post-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

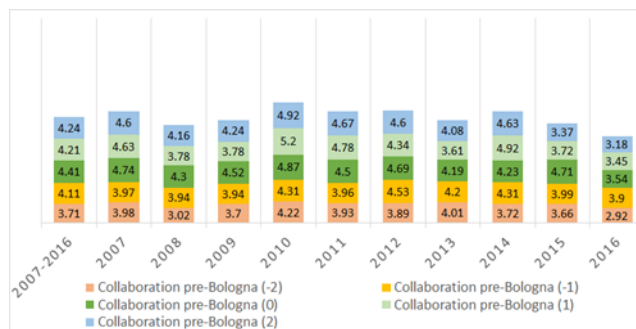


Figure 17 Average collaboration of the pre-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

When considering the average number of co-authors per publication (Figure 18), it is observed that this is the most stable indicator among the ones considered. For the pre-Bologna Ph.D. graduates, it is, on average, slightly higher than three, dropping below that number only in 2016, due to already explained reasons. For the post-Bologna Ph.D. graduates, slightly higher values were observed, but the trend is constant, except for the years up to 2011.

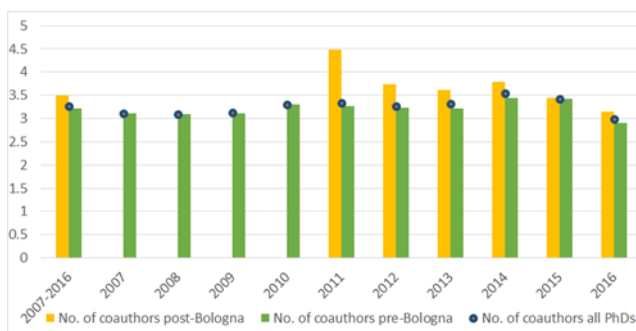


Figure 18 Average number of co-authors per publication of the pre-Bologna and the post-Bologna Ph.D. graduates in Slovenia between 2007 and 2016

This trend (the year-over-year decline of the average number of co-authors per publication for the post-Bologna Ph.D. graduates) is aligned with the growing independence presented in Figure 11.

Figure 19 for the post-Bologna Ph.D. graduates and Figure 20 for the pre-Bologna Ph.D. graduates show a growing number of co-authors from the year -2 until the year of their thesis defense (inclusively), and gradual decline in years +1 and +2 of the interval. The reason for this might be the independence that students gain after finishing their studies. Ph.D. graduates then have more knowledge and experience, which enables them to perform scientific research without additional help or at least at a lower collaboration level within individual publications.

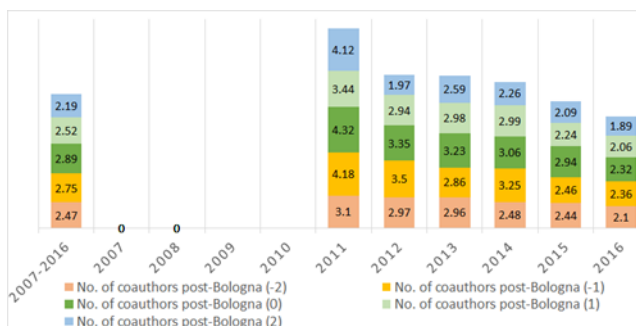


Figure 19 Average number of co-authors per publication of the post-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

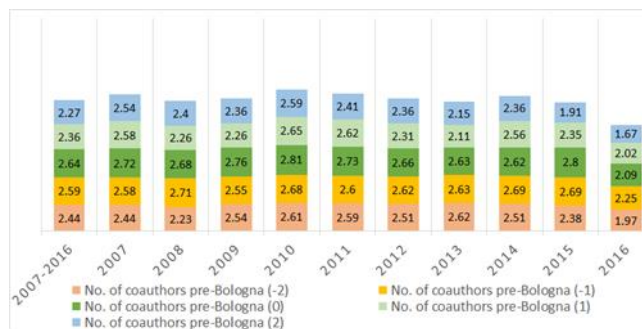


Figure 20 Average number of co-authors per publication of the pre-Bologna Ph.D. graduates in the ± 2 -periods in Slovenia between 2007 and 2016

6. Discussion

The results of the present study show that the Bologna reform affected the scientific publication performance of the Ph.D. graduates in all four considered aspects/indicators, although the impact on some of them has only been detected after a more detailed analysis. We can confirm two of the hypotheses and reject the other two. Below, we summarize our findings for each of the hypotheses separately.

(H1) *The scientific productivity of the post-Bologna Ph.D. graduates compared to the pre-Bologna Ph.D. graduates is significantly lower.*

The first hypothesis is rejected, since the data in Figures 2–4 show there was no significant difference in the average productivity of the post-Bologna Ph.D. graduates compared to the pre-Bologna Ph.D. graduates. Moreover, since 2013, the post-Bologna group performed better than the pre-Bologna group did. This is in line with the goals of the Bologna reform, which foresaw the better research abilities of students. However, the values of the average productivity are far from the numbers that pre-Bologna Ph.D. graduates had been achieving in the years before 2013. These values show results that are in line with other studies that generally observed a reduction in the quality of research papers (Gevers 2014). In contrast, the decline of productivity for pre-Bologna Ph.D. graduates in the last analyzed years was expected, since those are the students who did not finish their studies on time. The low values of the average productivity for post-Bologna Ph.D. graduates are, in this sense, more worrying.

(H2) *The Bologna reform stimulated an increase in the rate of foreign co-authors among Ph.D. graduates' collaborators.*

This hypothesis is confirmed. In every year, the post-Bologna Ph.D. graduates show higher internationality than the pre-Bologna group does (Figure 8), which is in line with the envisaged promotion of mobility within the Bologna reform and increased international cooperation among HE institutions. The same results are shown when comparing individual years of the ± 2 -periods (Figures 9 and 10). This finding agrees with Kastrin et al. (2017), who showed that the internationality of Slovenian researchers, in general, is constantly increasing since the year 2000.

Considering this aspect, our research confirmed that the Bologna reform brought a positive impact on doctoral studies. However, we again observe a declining trend in the average values of internationality for both groups of Ph.D. graduates from 2007 up to 2016.

(H3) *The independence of post-Bologna Ph.D. graduates is lower compared to the pre-Bologna Ph.D. graduates.*

This hypothesis is confirmed as the average independence of the pre-Bologna Ph.D. graduates is higher than for the post-Bologna Ph.D. graduates in all years, except in 2015, when the values for both groups are almost the same (Figure 11). Regardless, the trend is decreasing for the pre-Bologna Ph.D. graduates over the years, whereas it is increasing for the post-Bologna Ph.D. graduates, which can be a positive sign.

However, the data for the ± 2 -periods are somewhat more worrying, since the values for the individual years for the post-Bologna Ph.D. graduates are much lower than the values achieved by the pre-Bologna Ph.D. graduates in the years before 2013 (Figures 12 and 13).

The same conclusion comes from the data on the average number of solo papers (Figure 14), which additionally reveals that the post-Bologna Ph.D. graduates are registering much lower values than the pre-Bologna Ph.D. graduates do, until the last two years, when they managed to perform better, but still with much lower values than of the pre-Bologna group in the years up to 2013. Altogether, a minor CAGR decrease is observed for the post-Bologna Ph.D. graduates, while the pre-Bologna Ph.D. graduates registered a more

significant CAGR decline. Since independence is an important scientific evaluation dimension (Van den Besselaar and Sandström, 2019), these research results require particular attention.

(H4) The collaboration activity, in terms of the number of distinct co-authors, is higher for the post-Bologna Ph.D. graduates compared to the pre-Bologna Ph.D. graduates.

Although Ferligoj et al. (2015) claimed, “In recent decades, structural changes appearing in science have encouraged scientific collaboration,” and Kastrin et al. (2017) observed that collaboration among researchers is growing in Slovenia, this hypothesis is rejected based on the data used for our research. The results in Figure 15 reject the hypothesis, since the values for the post-Bologna Ph.D. graduates are even lower than the values for the pre-Bologna Ph.D. graduates in the last three years. Note that the values in the years from 2011 to 2013 are higher for the post-Bologna Ph.D. graduates. However, since in these three years, the number of post-Bologna Ph.D. graduates was still relatively small, their collaboration values do not contribute essentially to the overall picture. Therefore, on average, the collaboration of the pre-Bologna Ph.D. graduates is higher than the collaboration of the post-Bologna Ph.D. graduates in our researched timeframe.

However, in the year of the thesis defense, the data for the ± 2 -periods show (Figures 16 and 17) that the post-Bologna Ph.D. graduates recorded higher values on average than the pre-Bologna group did. Nonetheless, a slight decrease in collaboration activities is detected from 2007 to 2016 in each of the five years of the ± 2 period in both groups of Ph.D. graduates.

To summarize, the results of our research show that the Bologna reform caused non-negligible changes in the scientific publication performance of Ph.D. graduates, and we observed that the post-Bologna Ph.D. graduates perform better in two of the four indicators.

7. Conclusion

In this paper, we analyzed the impact of the Bologna reform based on differences in scientific publication performance among the Ph.D. graduates in Slovenia. We examined these differences using four indicators of scientific publication performance that capture different aspects of research activities. The results are interesting and, in some cases, surprising. The main conclusion is that the Bologna reform has some positive impact on Ph.D. graduates’ scientific publication performance. More concerning results of our analyses are the side findings that all indicators record declining trends in the 2007-2016 period.

It would be interesting to compare our results with data for other countries that also implemented the Bologna reform. Such comparison would lead to more solid conclusions and assessments of the advantages and disadvantages that the reform brought.

We analyzed a relatively short period of 10 years, which was selected to capture the transitional period, covering only the pre-Bologna Ph.D. graduates, and both the pre-Bologna and the post-Bologna Ph.D. graduates. Due to the selection of the five-year intervals of individual Ph.D.’s publication records, we were only able to track Ph.D. graduates that finished studies at the latest in 2016, in order to have complete publication records for each Ph.D. graduate (i.e., for a Ph.D. graduate defending his/her thesis in 2016, we used her/his publication records from the period of 2014–2018). Nonetheless, the relatively short period that we analyzed is recognized as a limitation of our research, as we are aware that such large-scale reforms have long-term impacts, which cannot be detected in a very limited time frame.

The scientific contribution of this paper thus stems mainly from the fact that to date (and to the best of our knowledge) nobody has analyzed the impact of the Bologna reform as directly as we have in this paper. Moreover, our analyses include the whole population of students that graduated in a country that implemented the Bologna reform.

We focused on Ph.D. studies and, within that, on Ph.D. graduates’ scientific publication performance to understand how that research activities of Ph.D. graduates have changed due to the implementation of the Bologna reform. Did it bring increased scientific productivity, collaboration, internationality, and independence? Our main research findings show that it mostly did not when considering the values over the whole set of Ph.D. graduates. However, our data also show that, in the analyzed indicators, the post-Bologna Ph.D. graduates are doing better in general compared to pre-Bologna Ph.D. graduates. This implies that the Bologna reform nonetheless has some positive impact in general, but since more and more students decide to study at the doctoral level, quality could be suffering due to increased quantity.

Does this mean that the standards were lowered? Should they be tightened so that fewer students could obtain Ph.D., or should the number of available spaces also be reduced to ensure that only the best candidates could enroll in Ph.D. studies?

We believe this would be a mistake. The increasing number of Ph.D. graduates working in non-academic companies and institutions (as all cannot stay in academia due to the limited number of available positions), where the direct transfer of knowledge occurs, increases national competitiveness in the long term, provided there is not as significant a brain drain as can be observed in Slovenia. More Ph.D. students coming from non-

academic companies and institutions also connect universities and their employers, thus decreasing the gap between them.

In contrast, particular attention should be paid to standards. Ph.D. students employed outside of academia might show tendencies to finish Ph.D. research mostly to bring competitive advantage to their businesses, which can even support their study for this reason. Therefore, appropriate balance and focus on quality and scientific contribution are mandatory.

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