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The Research Environment in a Developing Economy: Reforms, Patterns, and Challenges in Kazakhstan

Diana Amirbekova, Timur Narbaev * and Meruyert Kussaiyn

Business School, Kazakh-British Technical University, Almaty 050000, Kazakhstan
* Correspondence: t.narbaev@kbtu.kz

Abstract: Kazakhstan has implemented numerous policy reforms to improve its research environment since 1991, experiencing both positive changes and critical challenges. In this study, we conduct a comprehensive investigation of the country's research environment. Our materials include statistical data, science policy reports, bibliometric data from Scopus, and interview responses. Using descriptive statistics and regression analysis, we analyze the country's publication capacity, key characteristics, and science funding by the government. We critically review significant policy reforms and conduct interviews with subject matter experts. Our findings suggest there has been an increasing number of publications and growth in citations since joining the Bologna process in 2010, and that there is a high positive correlation between the volume of science funding and publication output, development levels across fields of science, and focus from science on commercialization of science. The challenges relate to publishing in international journals, government financing and commercialization, researcher capacity, scientific areas, and international collaboration. Our contributions to scholarly communication and science policy are two-fold. First, we present the relationship between several factors/policies and the research environment. Second, we reveal the main challenges Kazakhstan and its academic community have experienced which can be considered by stakeholders, including the government, academic institutions, researchers, and other developing countries.

Keywords: developing economy; Kazakhstan; publication pattern; research challenges; research environment; science policy reforms

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Citation: Amirbekova, D.; Narbaev, T.; Kussaiyn, M. The Research Environment in a Developing Economy: Reforms, Patterns, and Challenges in Kazakhstan. *Publications* **2022**, *10*, 37. https://doi.org/10.3390/publications10040037

Academic Editor: Kate Williams

Received: 8 July 2022
Accepted: 22 September 2022
Published: 3 October 2022

1. Introduction

Kazakhstan has implemented significant reforms and faced critical challenges in developing its research environment and capacity since its independence in 1991 [1,2]. The research capacity of a country is defined as the set of skills, abilities, and infrastructure that institutions and researchers use to conduct and maintain quality research [1]. The pioneering areas of science in Kazakhstan during the Soviet Union period in the 1980s were in fundamental mathematics, physics, and chemistry. Wang et al. [3] studied the state of the art of science in Central Asian countries and identified that, regionally, Kazakhstan had stronger research capacity in 1990 than it did later, during the 1990s. Major reforms during the 1990s, as a response to reanimate research capacity after the collapse of the Soviet Union, failed to offer the expected solutions or resulted in harsh outcomes. Among others, this included an outflow of researchers from science, an age gap between younger and older generations of scientists, and a decline in overall publication output and quality [1,4,5].

However, the reforms during the 2000s, mainly targeted at joining the Bologna declaration, were instrumental in reshaping and improving science in the country [6]. The new three-level educational system (bachelor, masters, and Ph.D.), the autonomy of a Higher Education Institution (HEI) in developing programs and curricula, and student/faculty mobility programs implemented during the decade led to the successful joining of the Bologna declaration in 2010 [7–9]. The declaration relates to a member country's integration process into the European quality assurance framework in education through improving mobility, lifelong learning, and the credit system. This profoundly impacted the country's education and building of research capacity [10].

In addition to the reforms in education, there were specific policies to improve the country's research capacity. In particular, the promotion of researchers, based on the quality of their publications, the introduction of best researcher awards, and abolishing the candidate/doctor of science degree programs in favor of Ph.D. programs were some of the most crucial policies. Such policies enhanced publication quality and shaped the research environment towards internationalization [10–12].

Along with the positive changes, the country experienced critical challenges in developing its research environment. Examples included a low level of financing and commercialization of science, a continuing English language barrier, and insufficient modernization of the research infrastructure [2,8,9]. As a result, this led to a low quality of research in some areas, difficulties in attracting and retaining qualified research staff, poor cooperation with the international research community, and publications in predatory journals. We note that in the research environment of Kazakhstan, commercialization of science is defined as the practice of implementing scientific results to the market through offering new or improved goods and services and is aimed at earning income.

In this study, we aim to analyze the research environment in Kazakhstan. Our investigation takes multiple analytical perspectives and is, therefore, comprehensive. We analyze the country's publication output and its government funding. Then, we study in more detail the specific publication characteristics across numerous fields of science. Next, we critically review significant science policy reforms and the fundamental changes they brought, using qualitative content analysis. We then extend our analysis by conducting interviews with subject matter experts. We corroborate our results from these multiple perspectives to narrow the consistent findings and provide recommendations for various stakeholders interested in developing science in a country or HEI. The data for our study were collected from various sources, including the government of Kazakhstan with its policy reforms and statistics on science, the Scopus database, and interviews.

We postulated the following research questions (RQs) to achieve our aim:

1. What are the key science policy reforms that shaped the research environment in the country?
2. What are the main characteristics of publication output that explain the environment in the country?
3. What are the main critical challenges and perspectives for improving the environment in the country?
4. What are the main recommendations, derived from our findings, for the government, HEIs, researchers, and other developing countries?

The contribution of our study to the body of knowledge on scholarly communication and research policy is two-fold. First, our findings show the relationship between several measures, on the one hand, and the research environment of a country, on the other hand. The critical measures represent the government support and funding, research productivity characteristics, fields of science, and science policy reforms that are likely to define the country's research environment and capacity. Second, we reveal the science policy reforms, patterns, and challenges Kazakhstan and its academic community have experienced in improving the research environment in the past three decades. Based on this, we provide numerous recommendations that can be helpful to our key stakeholders, including the government, HEIs, researchers, and other developing countries.

In the next section, we briefly review related literature on the research environment of a country, including its research productivity, characteristics, government support, and science policy reforms. We focus primarily on developing nations. Section 3 presents our data and methods, including actions and results we achieved in each step of our methodology. Then, we provide our main results and discuss key findings. Section 5 offers policy, managerial, academic, and exemplary recommendations for the government, HEIs, researchers, and other developing nations, respectively. In conclusion, we summarize our study and suggest prospective research avenues that can be pursued in future studies.

2. Review of Related Studies

The literature that investigates the research environment of countries, regions, or particular HEIs is extensive. In this section, we limit our review to the studies that addressed publication output and its characteristics, science funding by governments, policy reforms in science, internationalization of research, and challenges in the environment.

For example, Basu et al. [13] assessed the Chinese research environment by analyzing research productivity and technology development using such indicators as the investment volume into Research and Development (R&D), the number of articles published, the number of citations received, and the number of patents secured. The findings anticipated the country soon achieving a leading role in the global publication output, but was currently behind the United States and some European Union countries in citations received. Emphasizing government support, Xia et al. [14] examined the government's role in funding research activities in China. The study focused on reviewing fundamental research fields and explored their crucial performance aspects, such as innovation performance, economic performance, social performance, and international cooperation performance. They stated that more funds should be invested to ensure a higher research rate. At the same time, with favorable economic development, the importance of research could be increased.

Others focused on the impact of science policy reforms on the research landscape of a country, in general, and of HEIs, in particular. Korytkowski and Kulczyki [15] analyzed the impact of recent science policies on publication patterns in Poland. Applying the historical context analysis to the number and quality of publications, patents, and bibliometric indicators, the authors reviewed the policy regulations which led to overall growth in publication output. With a focus on the research impacts of HEIs, Herrera-Franco et al. [16] studied publication output in Ecuador over the period 1920–2020 and found that universities contributed 95.3% of the total number of publications. Rojko et al. [17] found that the academic mobility of students and Ph.D. programs in Slovenia, as part of the Bologna reforms in 1999, significantly impacted the publication performance of its Ph.D. graduates. Avanesova and Shamliyan [18] studied the publication output in Russian universities. They identified that state funding should be more transparent and better targeted at groups of researchers with a potential for further development. Such policy tools, along with investment in human capital, had an impact on stimulating publication activity. Therefore, they were considered an essential tool in shaping the publication landscape of the country.

Some studies presented empirical analysis to understand the relationship between the size of science funding (e.g., the Gross Domestic Product (GDP) spending) and the publication activity of a country. Chankseliani, Lovakov & Pislyakov [19] examined the scientific production in post-Soviet countries and empirically found that gross domestic expenditure on research and experimental development per researcher had a positive and strong correlation with the number of publications (proved by the correlation coefficient $r = 0.77$). According to their research, countries with higher expenditure, as a percentage of GDP, tended to have the larger spending per researcher. Wang et al. [20] conducted a similar study among Central Asian countries before and after the collapse of the Soviet Union in 1991. They found the highest correlation ($r = 0.92$) was between GDP spending and number of published papers. They also found that number of tourists and exports of fuel oil impacted publication activity. Focusing on selected countries in sub-Saharan Africa, Onyancha [21] identified the relationship between number of articles with their citations and economic development measured by the gross national income. The author found a weak, moderate, and strong statistical relationship between publication output and economic development, and the correlation strength varied from country to country. Overall, we note that such a type of statistical analysis helps to empirically understand the relationship between spending on science and its publication output.

Research productivity also differs across research fields. In the classification of the field of science and technology (FOS) provided by the Organisation for Economic Co-operation and Development (OECD), journals are grouped into six major fields of science [22]. They are the Natural Sciences, Engineering and Technology, Medical and Health Sciences, Agricultural and Veterinary Sciences, Social Sciences, and Humanities and Arts. According to Chankseliani et al. [19], Natural Sciences and Engineering and Technology were the two leading fields in publication output, and, compared to the other four, they also dominated in Kazakhstan. Some studies argue that such analysis across the fields is helpful in understanding leading and lagging research areas and can be useful for effective implementation of science policy reforms.

The Central Asian countries commonly have low investment in science. According to the UNESCO Institute for Statistics database, Kazakhstan, Kyrgyzstan, and Uzbekistan's GDP expenditure share on R&D is lower than 1.0% [23]. Another similarity is in the leading and lagging fields of science. Central Asian researchers were comparatively more profound and well published in Engineering and Technology and Natural Sciences fields, than in Social Sciences, Humanities and Arts, and Medical and Health Sciences fields. This report offered a comparative analysis of these countries across multiple research performance indicators (e.g., publication trend, publication output, citation rate, collaborating countries) [23].

While there are multiple studies which focus on other developing countries, we limited our review to several that investigated the above selected countries (e.g., Poland, Ecuador, and others from Central Asia). These developing countries are similar in their research environment size and structure, and the above studies explored challenges (e.g., improving their publication output, raising investment into science, improving policy reforms) which are comparative to the ones faced by Kazakhstan.

3. Data and Methods

3.1. Data

Table 1 presents our research approach. In Step 1, we collected the data for our study from three main sources. The first source included official documents, reports, and statistical data on education and science [24]. Second, we collected articles and their bibliometric information from Scopus and grouped them into the six major fields of science, according to the OECD's FOS Classification [22]. The third source was from open-ended interviews with four government officials.

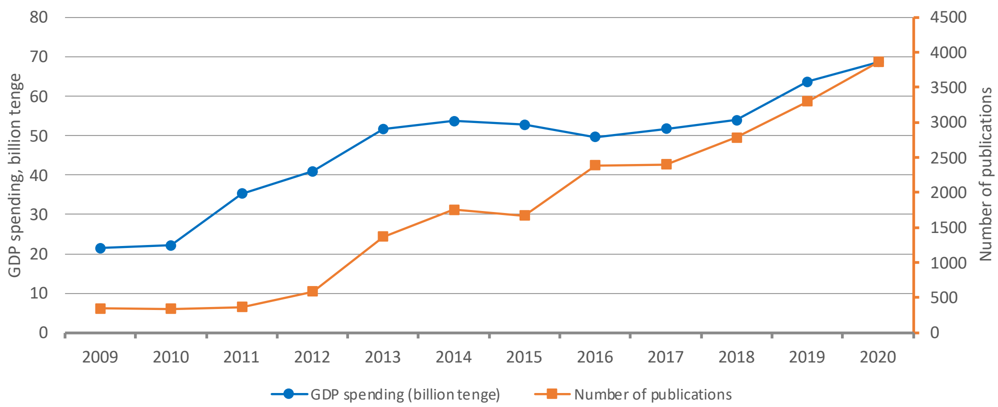

Figure 1. The trend in the GDP spending and published papers for 2009–2020.

Table 1. The research approach of the current study.

Steps and Research Questions (RQs)	Data	Description of the Methods	Outcome
Step 1: Data collection RQ: Not applicable	Comprehensive data on science policy reforms, GDP spending on science, and publication characteristics in Kazakhstan	Data from the Statistical Agency of the Republic of Kazakhstan, official reports, laws, and regulations (Source 1); searched for papers with authors' country affiliation as "Kazakhstan", limited to articles and reviews published in journals in English in the Scopus database (Source 2); and conducted interviews with four government officials (Source 3)	Available data for further analysis on science policy reforms (Step 2), publication trend and GDP spending (Step 3); 21,161 journal articles including their citation rate, number of researchers, and collaborating countries (Steps 3 and 4); recorded responses from the four interviews (Step 5)
Step 2: Review of the science policy reforms RQ-1: What are the key science policy reforms that shaped the research environment in the country?	Data on the science policy reforms (Source 1)	A subjective content analysis of the science policy reforms in Kazakhstan for the period1991–2020	Section 4.1, summarized the major policy reforms and their key changes in Table 2
Step 3: Analysis of the publication trend and GDP spending on science RQ-2: What are the main characteristics of publication output that explain the environment in the country?	Data from the Statistical Agency of the Republic of Kazakhstan on the GDP spending (Source 1) and published papers and journals (Source 2)	A descriptive analysis of the number of articles, journals, GDP spending and its share for the period 2009–2020. Trend and regression analyses of GDP spending and published papers for the period 2009–2020	Section 4.2, summarized the results of the descriptive analysis in Table 3, trend analysis in Figure 1, and regression analysis in Figure 2
Step 4: Examination of publication characteristics across OECD's six major fields of science RQ-2: What are the main characteristics of publication output that explain the environment in the country?	Data from the Statistical Agency of the Republic of Kazakhstan on the number of researchers (Source 1) and published papers, citations, and collaborating countries (Source 2)	A descriptive analysis and classification of the publication characteristics including the number of papers, citations, researchers, and top 5 collaborating countries across OECD's six fields of science and over the period 2009–2020.	Section 4.3, summarized the results of the classification of the number of papers, citations, and researchers in Table 4, and top 5 collaborating countries in Table A1 in Appendix A
Step 5: Analysis of the interview responses RQ-3: What are the main critical challenges and perspectives for improving the environment in the country?	Recorded responses of the interviews with four government officials conducted online on Zoom and Microsoft Teams in Russian and translated into English (Source 3)	A subjective analysis of the interview responses to reveal the current state of the research environment, the challenges in conducting research, and the opportunities for improving science in the country.	Section 4.4, the main reflections are summarized as publishing in international journals, government financing and commercialization, researcher capacity, scientific areas, and international collaboration, in Sections 4.4.1–4.4.5, respectively
Step 6: Discuss the key findings and derive the main recommendations RQ-4: What are the main recommendations for the government, HEI, researchers, and other developing countries derived from our findings?	All data	Based on the results, elaborative discussion of the main findings of the study, derived the main recommendations, and suggested future research directions	Discussion of the main findings in Sections 4.1–4.4, the main recommendations from the study for the government, HEIs, researchers, and other developing countries in Section 5, and future research directions in Section 6

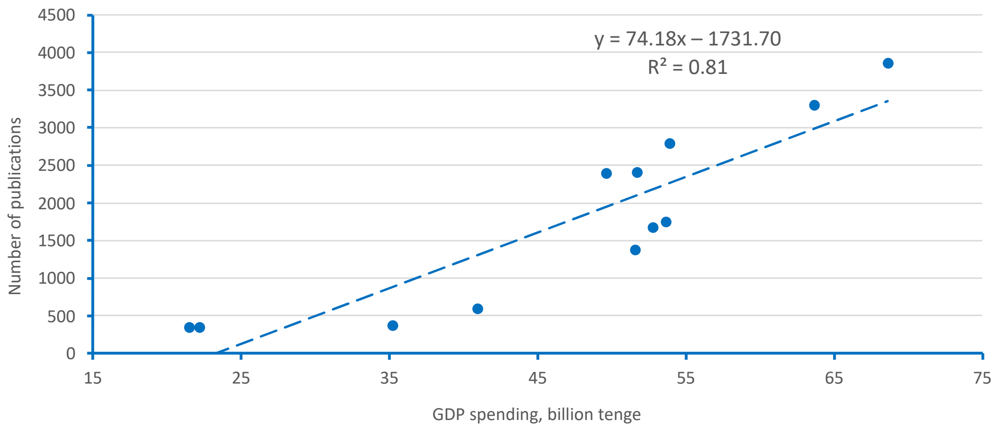

Figure 2. The relationship between GDP spending and published papers.

Table 2. Major reforms in education and science in Kazakhstan.

Year	Major Reforms	Key Changes
1992	Enactment of the Law on Education	Abolishing the Soviet higher education system, introducing private financing, and launching private universities.
1999	Enactment of the new Law on Education	Autonomy to determine the content of academic programs (curriculum, structure) by HEIs.
2004	Launch of the State Program on the Development of Education for 2005–2010	An experimental movement toward the new three-level educational system (bachelor, master, and Ph.D.) for HEIs, increase in the number of faculty with academic degrees and titles.
2005	Introduction of the Annual grants for the Best University Teacher	Recognition of outstanding achievements of faculty in teaching and research.
2010	Joining the Bologna Declaration	A complete movement to the three-level educational system, introduction of international academic mobility, and integration into the European quality assurance framework.
2011	Enactment of the Law on Science	In addition to teaching activities, increased focus on scientific activities in HEIs, emphasis on social aspects of faculty work and conditions (social support and job securities).
2015	Enactment of the Law on the Commercialization of the Results of Scientific and (or) Scientific-technical Activities	Growth of the commercialization of the outcomes of scientific activities, such as through grants for commercialization and modernization of research infrastructure.
2016	Launch of the State Program on the Development of Education for 2016–2019	Focus on science's contribution to economic development, the growing role of research-oriented faculties, improved corporate management.
2021	Launch of the National Project "Technological breakthrough through digitalization, science and innovation" for 2021–2025	A substantial focus on science: increasing the number of young researchers, modernization of the infrastructure of research institutes (in addition to HEIs), digitalization of research infrastructure, emphasis on global indexing platforms, commercialization of research outputs and patents, reduction of bureaucracy in science.

Table 3. The publication output and GDP spending on science in Kazakhstan.

Characteristics	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Number of articles	346	341	368	590	1369	1752	1669	2386	2400	2783	3297	3860
Number of journals	204	207	254	318	447	607	700	804	969	1111	1310	1515
GDP spending, billion tenge	21.48	22.19	35.25	40.96	51.57	53.65	52.80	49.65	51.69	53.91	63.66	68.61
GD spending share, %	0.13	0.08	0.12	0.13	0.14	0.14	0.13	0.10	0.10	0.09	0.09	0.13

Table 4. Key publication characteristics across OECD's six fields of science.

Characteristics	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Natural Sciences												
Number of articles	263	239	262	362	678	1160	931	1379	1201	1377	1845	2260
Citation per article	0.87	1.50	1.20	2.00	1.24	0.91	1.80	1.33	2.33	2.37	2.55	2.51
Number of researchers								5207	4983	5281	5396	5640
Engineering & Technology												
Number of articles	116	114	101	153	207	297	368	739	637	754	1085	1340
Citation per article	0.66	0.95	0.99	1.65	1.49	1.18	1.56	1.07	2.07	2.93	2.80	3.06
Number of researchers								4661	5039	4785	4692	4768
Medical & Health Sciences												
Number of articles	24	30	40	60	97	173	295	387	305	395	462	674
Citation per article	2.25	1.64	1.47	2.58	1.86	5.22	2.56	7.31	13.40	10.58	5.06	9.01
Number of researchers								1334	1051	1036	927	1007

Table 4. *Cont.*

Characteristics	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Agricultural & Veterinary Sciences												
Number of articles	32	40	38	39	75	115	151	165	218	209	275	330
Citation per article	1.23	1.10	1.57	2.21	1.93	1.22	0.91	1.76	1.66	1.76	1.75	1.76
Number of researchers								2089	1942	1847	1670	1714
Social Sciences												
Number of articles	21	32	34	120	171	240	449	846	706	863	873	988
Citation per article	0.94	1.42	2.01	0.77	0.57	0.63	0.95	0.58	0.72	1.17	1.41	1.63
Number of researchers								1504	1440	1891	1616	1702
Humanities & Arts												
Number of articles	3	6	7	15	20	73	225	131	252	266	301	239
Citation per article	0.56	3.29	1.13	1.09	0.76	0.65	0.35	0.27	0.35	0.94	0.56	0.77
Number of researchers								2626	2750	2614	2823	3397

Note: the statistics on the number of researchers is effective from 2016.

3.2. Methods

In Step 2, we qualitatively analyzed science policy reforms by reviewing the key official documents (laws, programs, regulations, and reports). We specifically focused on the periods before and after Kazakhstan joined the Bologna declaration. We selected 2009 as the year prior to joining the Bologna declaration. We selected this milestone as it presented a critical shift in scientific development. As substantiated in the Introduction, the joining of the Bologna declaration had a considerable impact on building research capacity in the country. Overall, this analysis also aimed to examine the close connection between the current research environment and government mechanisms in place to facilitate the evolution of this environment.

Step 3 covered the analysis of the publication trend and the regression of publication output versus GDP spending on science. The regression aimed to identify the relative impact of science expenditure on publication output in Kazakhstan.

Then, we analyzed the publication characteristics of Kazakhstan for the period 2009–2020 (Step 4). The analytical variables were the number of published papers, citation rate of publications, the number of researchers contributing to science, and collaborating countries across OECD's six fields of science.

Lastly, we conducted semi-structured interviews with four subject matter experts (Step 5). We followed Yin's method [25], which was helpful in collecting and analyzing information, such as opinions on a specific topic [26]. The interviews were conducted with the representatives of the Ministry of Education and Science of the Republic of Kazakhstan and the other two agencies that coordinate the education and science system in the country. The four interviewees represented these three organizations. We created a list of questions to follow during the interviews conducted online on Zoom and Microsoft Teams and recorded the interviews. The results were transcribed and coded and, according to the questions, categorized into several groups. Overall, the questions aimed to reveal the current state of the research environment, the challenges in conducting research, and the opportunities for improving science in the country. We conducted all interviews in Russian and translated explanatory quotes into English.

4. Results and Discussion

4.1. Major Science Policy Reforms

The government of Kazakhstan implemented numerous reforms to improve overall education and research capacity and to establish a more competitive research environment. Table 2 presents the timeline of the major reforms with the fundamental changes the reforms have brought.

The government implemented fundamental reforms during the 1990s and the early 2000s. In the end, these reforms led to the country joining the Bologna declaration in 2010. The enactment of the Law on Education (1992) set a new educational system in Kazakhstan that included abolishing the Soviet higher education system and injection of private financing into education, e.g., through the launch of the private HEI. The government revisited this law for its effectiveness during the late 1990s and enacted the new Law on Education in 1999. Its reforms resulted in the modernization of the higher education system, including more opportunities for private financing, an increase in educational grants, and autonomy for academic curriculum development.

Further, the reforms under the State Program on the Development of Education for 2005–2010 (2004) mainly involved an experimental transition in moving HEIs towards the three-level higher education system, comprising bachelor, masters, and Ph.D. levels. The government focused not only on improving numeric metrics but also on stimulating quality changes. For example, the annual competition for Kazakhstan's best university teacher (2005) motivated HEI faculties toward more interactive teaching and engaged research with publications in international peer-reviewed outlets in English. Overall, the reforms of the 1990s and 2000s were fundamental and revolutionized the shift in education and science from Soviet standards to the standards within the Bologna declaration framework.

In 2010, the country joined the Bologna declaration marking a new era in education and science. The fundamental reforms of the 2000s were instrumental in the integration process of the country into the European quality assurance framework. All HEIs introduced and mandated the three-level education system, and opportunities for academic mobility of students and staff occurred. In science, this motivated the introduction of the new Law on Science (2011). It targeted science and its commercialization, including systematic financing of research, new requirements for faculty promotion and Ph.D. program candidates, and awarding of scientific degrees and research supervisor positions. The Law on the Commercialization of the Results of Scientific and (or) Scientific-technical Activities (2015) defined norms and regulations for scientific activities and publication outputs. The State Program on the Development of Education (2016) identified critical aspects related to improving the research environment, such as the development of scientific infrastructure, the introduction of specific mechanisms to improve science management, monitoring of scientific results, the contribution of local scientists to the global knowledge base, and their integration into the global scientific community. Lastly, one of the national projects approved in 2021 was "Technological breakthrough through digitalization, science, and innovation" for the period 2021–2025. It has specific target indicators to be achieved, such as young researchers, quality of publications, more effective management of the science system and commercialization, patents, and commercialization of publication outputs.

From this science policy perspective, we can group the evolution of the research environment into four phases. Such progress in the reforms highlights significant changes in Kazakhstan's higher education and science since gaining its independence. The following are a brief description of the four phases.

Phase I (1991–2004) was characterized by the new educational system of the independent country. It resulted in initial but fundamental changes to the new educational system, which was still immature. Phase II (2004–2010) covered the critical reforms in education and science that were instrumental in joining the Bologna declaration and introducing the new doctoral Ph.D. programs. Phase III (2011–2021) was mainly characterized by the internationalization of education and science. It also resulted in the shift from education into science, including the overseas preparation of researchers, new requirements for obtaining scientific degrees and ranks, and attention to publications in journals ranked in international databases, such as Scopus and Web of Science. Phase IV (2021-onwards) is aligned with The New Kazakhstan vision set by the government. A greater emphasis is to be given to introducing multiple grants for researchers annually, and a new approach to post-doctoral programs in the country. A critical reform in this phase includes a planned separation of the current Ministry of Education and Science into two new ministries (one responsible for basic education, including primary and secondary, and the other for higher education and science).

All these reforms resulted in changes that were both fundamental to advancing research capacity development and specific to boosting particular fields of science. Introducing the new laws on education, science, and commercialization affected mechanisms that manage the activities of HEIs, research institutes, and scientific staff, and stimulated commercialization activity. Recognition of researchers and their contribution to science promoted an individual level of motivation and new opportunities for researchers. Overall, the consistent changes shifted science in new directions to diversify its impact and contribution to multiple fields in research.

4.2. Publication Trend and GDP Spending

Table 3 shows that the number of articles in the journals indexed in Scopus has gradually risen since 2009. Such a positive publication trend results from the policy reforms implemented in the country in the late 2000s and early 2010s. We discussed this in detail in Section 4.1, including favorable conditions to publish in international peer-reviewed journals, which significantly boosted the publication activity of local researchers. However, it is noted that this growth can also be attributed to the size of Scopus (the number of journals) which grew during the period analyzed.

The term R&D is commonly used for the evaluation of science. It includes three main types of research: fundamental research; applied research; and experimental design and experimental development [22]. The national spending on R&D in Kazakhstan is identified as one of the fundamental indicators to assess the country's technological and scientific development. The spending level is calculated as the total amount of public and private expenditure, expressed as a percentage of GDP. In 2020, this indicator was equal to 0.13% of the country's GDP. As a benchmark, it was interesting to see the close forerunners to Kazakhstan in the academic field (counted by the number of articles in English in Scopus) and how much of their GDP they spend. Using the Scopus database and GDP related data from the World Bank [27], we found Lithuania, with 4040 articles, invested 1.16% of their GDP, the Philippines, with 4242 articles, invested 0.32% of their GDP, and Qatar, with 4343 articles, invested 0.53% of their GDP.

For our regression analysis, we removed the spending on experimental design and experimental development types of research. Unlike the first two types of research, national funding for experimental design and experimental development types of research does not require that the outcomes of the research projects are published in peer-reviewed international journals indexed in Scopus or Web of Science. This type of research instead requires that patents are received as an outcome of the funding, which is not an indented purpose for analysis in the current study. Therefore, we kept the total spending level on the fundamental and applied types of research only and expressed it as a percentage of GDP, the so-called GDP spending share (Table 3). We also note that the data on the GDP spending on science (fundamental and applied types of research) is not reported separately in Kazakhstan. Overall, we noted about a three-fold increase in this spending (from 21.48 billion tenge to 68.61 billion tenge) and about a ten-fold growth in the publication number (from 346 to 3860) for the period 2009–2020.

Figure 1 shows the growth in GDP spending on science and number of publications for the period 2009–2020. There was a gradual increase in both metrics. The regression analysis was performed using this information to understand the relationship between the GDP spending and the publication output in the country (Figure 2). As shown in the graph, the publication activity of researchers was positively correlated with investment into science, which is also given in Table 3. According to the regression analysis results, the coefficient of determination (R squared) equaled about 0.81. It meant that about 81% of the variation in the publication numbers was explained by variability in the GDP spending. The higher the coefficient of determination, the better the model. Overall, the correlation between GDP spending and publication patterns over the period 2009–2020 was positive, and the GDP spending could explain the good performance variance of publications.

4.3. Publication Characteristics across OECD's Fields of Science

Overall, publication output has been growing in all six fields of science over the examined period (Table 4). The Natural Sciences field contributed the most publications, followed by Engineering and Technology and the Social Sciences fields. Despite a leading place in the number of publications, the citation rate was not the highest in Natural Sciences. Medical and Health Sciences was a leading field with the highest citation per article values. We also noted an overall increase in this metric, that showed the attractiveness level of local researchers' work to the global research community. On the contrary, Humanities and Arts had the lowest number of publications and citations, while Medical and Health Sciences had the lowest number of researchers involved.

It is critical to note that financing of the fields of science depends on its priority for the government. Therefore, the major support goes in certain scientific directions in addition to economic preconditions and interest in particular research fields. Another finding was that, historically, and partly due to Soviet schools of thought, research in Natural Sciences, such as in chemistry, mathematics, and physics, has been strong and competitive in the global scientific community, compared to the scientific schools in other fields like Social Sciences and Humanities and Arts.

The trends in the key publication characteristics also help in understanding qualitative aspects related to staff development and research collaborations. Table A1 in Appendix A provides the information on the top five collaborating countries across OECD's six fields of science for 2009–2020. It shows the percentage of the total publications from Kazakhstan co-authored with researchers from other countries. This metric is helpful in understanding the level of internationalization in particular fields of science and over time. From this table, it was interesting to see if an increase in the collaboration level (sum of the percentages of the top five collaborating countries) helped to explain the increase in the number of publications and citations. We found this was true for some fields of science and during a particular period only. As an example, it was true for Social Sciences over the last three years (2018–2020). Overall, in summary to this, we derived mixed results both across the OECD's fields of science and over the analyzed period. We summarized this finding with the results from the analysis of the science policy reforms in Section 4.1 and the interviews in the following section of the paper.

4.4. Subject Matter Interviews

4.4.1. Reflections on Publishing in International Journals

Publishing research in international databases, such as Scopus or Web of Science, is an indicator of a researcher's contribution. The interviewees mentioned various opinions regarding current conditions, the quality of publications, and the journals selected.

Interviewee C mentioned: *"In general, what conditions are created. Only requirements are created. In general, we have Kazakhstani articles on Web of Science or Scopus, they have grown sharply after 11 years, because of what? Since the requirement to obtain a PhD was included, it is mandatory to have an article or obtain an associate professor or professor. That is all because of these requirements"*.

The number of papers published in predatory journals was relatively high in the past. Interviewee A provided some insights: *"This is a serious problem, and it will probably remain for many years, although we are slowly giving up leadership positions in this issue, earlier we were the first in the list of countries whose authors are published in predators . . . The problem remains and the root of this problem lies in the incompetence of the teaching staff of universities that trains doctoral students. Moreover, Elsevier and Clarivate are obliged to conduct 200 seminars annually, we have an annual subscription. Each organization has 200 webinars for authors, scientific editors and in general for everyone, so there is a lot of information, they know about it, but for some reason they do not want to make a conscious choice . . . "*.

The interviewees summarized that to stimulate the publication activity in international journals, local science should interest global publishers and the international community. However, the issues remain, and among other opportunities is the need to investigate global level research topics. Overall, the experts' opinions, related to the publication practice in international outlets, mirrored the results of the policy reforms on the internationalization of science. The wider internationalization shift in the research environment in Kazakhstan (elaborated in Section 4.1 as part of Phase III's reforms over 2011–2021) targeted overseas research staff development, implementation of more advanced requirements for obtaining scientific degrees, and stimulating publications in international journals indexed in Scopus and Web of Science.

4.4.2. Reflections on Government Financing and Commercialization

The importance of financing is critical in science in Kazakhstan. The increasing number of research grants and policy reforms to increase the funding to 1.00% of GDP by 2025 highlight the importance of the mechanisms in place. However, the interviewees expressed concerns about whether this money would be enough. Interviewee C mentioned: *"Only the state cannot provide 1%, this is not enough—we will catch up with Russia and Belarus, we will not go any further. Therefore, 1% is not enough, it was not clear how subsoil users (Authors' note: subsoil users are organizations carrying out operations in the field of production and turnover of oil, gas, uranium, coal, and other resources in the mining sector) to influence, and now the fact that it will go through centralization is good, it seems to me that all large enterprises should allocate money for science, not like subsoil users, but we have many large enterprises . . . Universities have extra-budgetary funds. For example, students pay tuition fees, while universities allocate a minimal amount. It seems that universities should allocate money for exploratory research, joint efforts with enterprises, not only through the state budget, only then it seems that funding for science will increase in Kazakhstan".*

Quite the opposite opinion was expressed by Interviewee B: *"I calculated, now in 2020 we have such figures as about 70 billion tenge, in absolute figures, in shares it is about 0.12%. We plan to bring it up to 1.00%. I figured it was 610 billion tenge, it is more than 1 billion 660 million dollars . . . Imagine this amount and think whether it is real or not. Is this a real task? In my opinion, this is more like a discursive practice than a clearly defined task".*

However, as our comparative analysis showed in Section 4.2, this value was equal to 0.13% of the country's GDP in 2020. While the close forerunners (e.g., the Philippines, Qatar, and Lithuania), measured by the number of papers published, have considerably higher spending (0.32%, 0.53%, and 1.16%, respectively), the GDP spending on science in Kazakhstan is currently far from the targeted 1.00% to achieve by 2025.

Interviewee D raised a concern about the results of financing related to the commercialization of research: *" . . . Why we have a low level of commercialization of scientific developments, that, of course, our market is not yet so developed . . . In our country, if you look at the statistics of the National Center of Science and Technology Evaluation, we have the results of each state programs being completed there as scientific reports only . . . Well, this is the answer to the question why Kazakh scientific developments remain gathering dust on the shelves. Based on experience, I answer this question: because maybe they have commercial potential, but they cannot present it? That is, they need to work even further. Who will work? The task of the commercialization office. But the commercialization office does not do this, why, because again there are many problems here. Who works in these commercialization offices, do they have competence in this area? Usually, these commercialization offices are run by the same scientists from the same university or research institute . . . ".*

Interviewee B noted: *"We wrote letters, all these research institutes that took part, why is it so, you left, you have experimental tests, for example, you have passed, you have already entered R&D, but what did not go further into the economy? And they tell us: "We have a study for three years. That is, in three years we must come up with something, make prototype, work out this prototype. Every year we have a budget cut, cut, cut. We do not have time to transfer it to industrial tests. But after industrial there is still a huge R&D chain. There is also market research, where to* *sell, advertise well, find an investor. And here everything is already, and it turns out for us, by and large, that the money that was invested, the results were obtained, but they were obtained at the research stage. It is necessary to include an additional stage so that it is no longer scientists who are engaged, but marketers and so on are already connected"*.

In the context of the Kazakhstan research environment, the commercialization of science is defined as the process to apply research outcomes into practice as goods or services, with the key requirement to earn income. The analysis of the major science policy reforms in Section 4.1 shows that the research environment in Kazakhstan, overall, has progressed from focusing on education (resulted in joining the Bologna Declaration in 2010), to science (enactment of the Law on Science in 2011), to commercialization of science (enactment of Law on the Commercialization of the Results of Scientific and (or) Scientific-technical Activities in 2015). Apparently, with continued improvement of the overall research environment (the researcher capacity, publication practices, and international collaboration), the commercialization of the research outcomes will be one of the main issues in the government agenda in the 2020s.

4.4.3. Reflections on Researcher Capacity

The interviewees expressed a common opinion regarding the current state of researcher capacity and quality of publications.

Interviewee A said: *"There is still a layer of adult faculty in universities who have not defended a degree, who want to get a degree, a Ph.D. degree, they are those who do not know English, they do not enter our doctoral studies, but then, in order to achieve their goals, they enter graduate school, doctoral studies in neighboring countries, most often Kyrgyzstan, then come back to us and apply for recognition"*.

Moreover, Interviewees B and C recognized the current state in the light of the above reforms and financing approach. They summarized that the major factors that hold back the development of scientists is the low attractiveness the younger generation has for doing research.

Interviewee A mentioned that " … *tools as a research supervisor and international research internships are not used enough* … *it is a role of universities, and we need to increase their responsibility* … ".

The interviewees confirmed the shifts that happened in the preparation of scientists but also indicated some factors that hold back the current development of science. The interviewees described the importance of various stakeholders in science development well, mentioning the role of commercialization offices, universities, and scientists.

4.4.4. Reflections on the Scientific Areas

The experts shared their knowledge on awareness of specific areas aligned with the priority areas for the Kazakhstani economy.

Interviewee A mentioned *"natural sciences–physical, chemical, biological, biotechnology ecology, technical sciences–metallurgy, power engineering, chemical technology, food technology, engineering technology, in humanities–pedagogical sciences"*.

Regarding the potential areas for future research, Interviewee C mentioned pharmacology, agriculture, information technology, and biotechnologies. We corroborated this with the findings of the analysis of the publication characteristics across the OECD's fields of science (Table 4). We saw a substantial increase in the publication output in Natural Sciences, Engineering and Technology, and Medical and Health Sciences fields, moderate growth in Agricultural and Veterinary Sciences and Social Sciences fields, and stagnation in the Humanities and Arts field in the last five years.

4.4.5. Reflections on International Collaboration

International collaborations are considered a crucial part of research activities. Concerning attracting international scientists, one of the interviewees noted that there are no limits to establishing partnerships but how to do that depends on their purposes.

The interviewees shared a similar opinion, stressing the initiatives that need to come from researchers who are responsible for establishing such links. This was highlighted in the policy reforms analysis since joining the Bologna Declaration in 2010.

Interviewee D mentioned: *"Here we need to understand why, well, we need foreign partners for what purpose. I have such an opinion, first we must prepare the ground for this, to cooperate with foreign partners, we need export-oriented projects . . . A lot of companies abroad are hunting for good ideas, you know. Here, too, I would not like them, relatively speaking, to buy these technologies for cheap at the stage of completion of scientific developments, you understand. Because they will already have a workable business model, a financial model, and the first commercial sale, that is, feedback from their potential buyers. They could sell for $100,000 at the research stage in the form of a report, but they can sell for $10 or $100 million in the product development stage. Understand the difference, right? Here, new jobs would be created at the testing stage, tax revenues to the Kazakhstani budget, do you understand?"*.

In summary, the analysis of the interview responses helped to reveal more insights on the current research environment in Kazakhstan. The interviewees expressed their subject matter opinions from the science policy standpoint. These covered international journal publishing issues, government financing and commercialization, researcher capacity, scientific areas, and international collaboration.

The interview results indicated that publications in international journals and research support should also result in the commercialization of research and its contribution to the country's economy. Recent policy changes in science confirm that the requirements for quality research are introduced at the early stages of academic staff development. They stated that close collaboration between the scientific community and business community would result not only in published articles but also in commercialization, patents, and their application.

The importance of government financing was mentioned several times, which is critical for science. This includes a noticeable increase in research grant projects available to the researchers. Financing in the last three years has dramatically improved, but was still lower than in some neighboring countries.

The significant shifts in improved researcher capacity, when Kazakhstan joined the Bologna declaration, were related to training research staff with Ph.D. degrees. The number of scholarships for Ph.D. programs is increasing each year as are the requirements set for Ph.D. applicants. One of the main requirements is to publish articles in international journals indexed in Scopus or Web of Science. These have impacted the number of publications in Kazakhstan since 2011. Moreover, the English language as an entry requirement is a must, which positively impacted publication activity and quality.

5. Recommendations

The major findings of our study revealed the overall publication trend, government financing of science, key publication characteristics, their distribution across the OECD-defined six major fields of science, science policy reforms, and experts' opinions. They all help to understand the current state of the research environment in Kazakhstan, including the reforms, patterns, and challenges the environment has experienced and is currently facing. Based on the analysis of these findings, we derived the following recommendations that could be helpful for further development. We grouped these recommendations in terms of the key stakeholders who could consider our findings.

5.1. Policy Recommendations—For the Government

The government's support of science and the policies implemented during the three decades of the country's independence have played a crucial role. GDP spending on fundamental and applied types of research improved the overall research capacity in terms of publication number and quality. However, the plan of the government to increase GDP spending share from the current 0.10% to 1.00% should be taken with caution. The expert feedback from the interview suggested a few points to achieve this plan and tackle common issues. Another notable concern was an improved commercialization mechanism and integration of the scientific and business communities. The government should pay more attention to these issues. It is known that the R&D stage is critical for further developing research ideas and their possible results. Therefore, it requires funding that might not necessarily result in financial outputs. In this regard, R&D commercialization mechanisms should be introduced in various research areas to minimize government funding and encourage private business participation in science. Integrating scientific and business communities is essential in generating constant research development for the needs of business and society and in attracting additional financing.

5.2. Managerial Recommendations—For HEIs

The recommendations for HEIs are to focus on the following aspects: attraction and retention of qualified staff, internationalization of their faculties and research works, and investments into their research infrastructures. First, the systematic efforts of the government to support the younger generation of scientists with the introduction of government grants for Ph.D. programs, scholarships, and faculty promotion had positive outcomes overall, but also led to unexpected results (e.g., an enormous number of publications in predatory journals, mainly, for the sake of fulfilling their publication requirements). The issue was especially highlighted in the beginning when Ph.D. programs were introduced, and universities faced the challenge of assigning supervisors that were familiar with the Bologna system. The English language barriers of the older generation of scientists limited potential opportunities for integrating local research into the global community. Second, the internationalization of research has become a problem that needs to be solved. In this regard, providing autonomy to HEIs should play a key role in funding and collaboration with foreign institutions at a university level. Third, research financing should be consistent and be a foundation for identifying potential directions for further research. The long-term orientation of financing might generate positive and sustainable results in research infrastructure development.

5.3. Academic Recommendations—For Researchers

The research findings revealed recommendations for researchers in the following directions: mechanisms to boost research activity and cooperation and to identify research areas with high growth potential. There is a gap in research in this direction, due to Kazakhstan's early stages of scientometrics and science research. The current higher education system creates conditions, but, on the academic level, there is still a gap that should scientifically define areas of potential growth and collaboration to support the existing scientific system and define directions for future consistent growth. Identified problems indicated some concerns regarding research activity and cooperation on a global level. This study provides the analysis and understanding of potential growth areas and directions where such cooperation could be taken further.

5.4. Recommendations for Developing Countries

Some of our findings are useful for other developing countries that face similar reforms and challenges in improving their research environment. The recommendations are around the effects of the science policies implemented by Kazakhstan that resulted in an improved research capacity. Table 4 provides the country's experience in implementing the specific reforms and the changes the reforms brought. The shift from the Soviet education and science system to the standards within the European quality assurance framework (the Bologna declaration) constituted a significant milestone in improving the research environment in the country. The findings from the interviews, especially related to those aspects that require improvements (commercialization of research outputs, involvement of foreign collaborators, particular research areas to concentrate on), could help other developing nations implement similar reforms.

6. Conclusions

Kazakhstan has implemented numerous major policy reforms in the past three decades to improve its publication profile and overall research environment. Along with the positive changes, the country experienced critical challenges in developing its research environment. In the current study, we conducted a comprehensive investigation of the research environment in Kazakhstan.

Our data were collected from various sources, which included statistics and reports by the government of Kazakhstan, the Scopus database, and interviews. We analyzed the country's publication output, key characteristics, and government funding using descriptive statistics and regression analysis. Using qualitative content analysis, we critically reviewed the major science policy reforms and discussed the fundamental changes they brought. To reveal the challenges that exist in the research environment, we conducted interviews with four subject matter experts. Lastly, we corroborated the results across our multiple analyses, summarized the findings, and provided critical recommendations for the government, HEIs, researchers, and other developing nations.

We note two main contributions of our study to the scholarly communication and science policy body of knowledge. First, we presented the relationship between several factors/policies and the research environment of a country. Second, we revealed the main patterns and challenges Kazakhstan and its academic community have experienced in improving its research environment, which are helpful to key stakeholders interested in developing a country's research environment.

The following limitations of the study could be addressed in future research. First, our scope was comprehensive, covering all fields of science, and future studies could focus on investigating specific fields in more detail. Future research could investigate fundamental and applied research fields separately from each other. In addition, research commercialization issues could be investigated. In the current study, we did not analyze the experimental design and experimental developments types of research that require the commercialization of scientific outcomes (e.g., patents). A bottom-up study could be performed by analyzing, for example, staff development and Ph.D. training performance in HEIs and their impact on the publication output of the country. Lastly, we focused on a single country, and future studies could offer a comparative analysis of the reforms, patterns, and challenges of the country's research environment with other developing nations.

Author Contributions: Conceptualization, T.N. and D.A.; methodology, T.N.; validation, T.N., D.A. and M.K.; formal analysis, D.A., M.K.; resources, T.N., D.A. and M.K.; writing—original draft preparation, D.A., M.K.; writing—review and editing, T.N., D.A.; visualization, D.A., M.K.; supervision, T.N.; project administration, T.N.; funding acquisition, T.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan, grant number AP08856031.

Data Availability Statement: The data presented in this study are available in the article.

Acknowledgments: The authors are thankful to the four interviewees, who desire anonymity, for participating in the interviews and sharing their expert knowledge on the matter.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Publication numbers, citations and collaborating countries with Kazakhstan across OECD's six fields of science during 2009–2020.

Characteristics	Natural Sciences	Engineering & Technology	Medical & Health Sciences	Agricultural & Veterinary Sciences	Social Sciences	Humanities & Arts
			2009			
Number of articles	263	116	24	32	21	3
Citation per article	0.87	0.66	2.25	1.23	0.94	0.56
Top 5 collaborating countries (% of Number of articles)	RF (30.4), US (14.4), UK (11.8), GE (11.4), UR (10.3)	RF (25), US (15.5), JP (9.5), UR (6.9), UK (6.9)	US (41.7), RF (25), KG (20.8), UZ (16.7), DN (12.5)	GE (15.6), RF (15.6), UZ (12.5), UK (12.5), US (12.5)	US (28.6), AU (9.5), SK (9.5), UK (9.5), CA (3.5)	SK (33.3), US (33.3)
			2010			
Number of articles	239	114	30	40	32	6
Citation per article	1.50	0.95	1.64	1.10	1.42	3.29
Top 5 collaborating countries (% of Number of articles)	RF (22.6), US (17.6), GE (12.1), UK (8.8), JP (7.9)	RF (21.1), US (14.0), GE (6.1), UR (5.3), GR (4.4)	US (46.7), RF (33.3), JP (20), AR (16.7), UZ (16.72)	US (17.5), RF (12.5), FR (10), UK (10), GE (7.5)	US (13), GE (6.3), ND (5.3), UK (3.5), AU (3.1)	US (33.3), GE (16.7), IN (16.7), ND (16.7), RF (16.7)
			2011			
Number of articles	262	101	40	38	34	7
Citation per article	1.20	0.99	1.47	1.57	2.01	1.13
Top 5 collaborating countries (% of Number of articles)	RF (24.8), US (12.2), GE (9.2), FR (4.2), SP (3.4)	RF (25.7), US (7.9), GE (5.9), UR (5), UK (5)	RF (30), US (15), AR (10), NW (10), AT (7.5)	RF (18.4), US (13.2), EG (10.5), GE (10.5), TR (10.5)	US (20.6), UK (8.8), MA (5.9), RF (5.9), GE (2.9)	UK (14.3), SK (14.3)
			2012			
Number of articles	362	153	60	39	120	15
Citation per article	2.00	1.65	2.58	2.21	0.77	1.09
Top 5 collaborating countries (% of Number of articles)	RF (21.3), US (14.9), GE (8), JP (7.2), UK (6.6)	RF (17), US (13.7), UK (7.2), PA (5.2), PO (5.2)	GE (23.3), JP (21.7), US (20), RF (18.3), ND (13.3)	UK (20.5), US (20.5), CH (17.9), RF (17.9), CA (7.7)	US (6.7), GE (5.8), RF (4.2), UK (4.2), PO (2.5)	RF (2.5), AU (0.8), BE (0.8), FR (0.8), ND (0.8)
			2013			
Number of articles	678	207	97	75	171	20
Citation per article	1.24	1.49	1.86	1.93	0.57	0.76
Top 5 collaborating countries (% of Number of articles)	RF (15.6), US (8.8), GE (6.6), JP (4.6), UR (4.1)	RF (16.9), US (12.1), GE (6.8), UK (6.8), UR (5.8)	RF (21.6), US (17.5), GE (10.3), ND (8.2), NW (8.2)	RF (16), US (13.3), GE (10.7), FR (9.3), CH (6.7)	US (12.9), UK (6.4), GE (5.3), AU (3.5), PO (3.5)	RF (10), US (10), CZ (5), GE (5), KG (5)

Table A1. *Cont.*

Characteristics	Natural Sciences	Engineering & Technology	Medical & Health Sciences	Agricultural & Veterinary Sciences	Social Sciences	Humanities & Arts
			2014			
Number of articles	1160	297	173	115	240	73
Citation per article	0.91	1.18	5.22	1.22	0.63	0.65
Top 5 collaborating countries (% of Number of articles)	RF (13.2), US (6.1), GE (4.7), UK (3.4), PO (2.7)	RF (14.8), US (8.4), PO (6.1), UK (5.7), UR (4.7)	RF (18.5), US (17.9), UK (13.3), GE (10.4), FR (8.7)	RF (18.3), US (11.3), CH (7), FR (7), BG (6.1)	US (4.6), UK (2.9), GE (2.1), RF (1.7), AU (1.3)	US (6.8), RF (5.5), GE (4.1), UK (2.7), AU (1.4)
			2015			
Number of articles	931	368	295	151	449	225
Citation per article	1.80	1.56	2.56	0.91	0.95	0.35
Top 5 collaborating countries (% of Number of articles)	RF (15.5), US (7.1), GE (6.3), TR (3.4), CH (3)	RF (16.6), US (6.8), PO (5.2), UR (5.2), GE (4.6)	RF (13.2), US (13.2), UK (8.1), TR (5.4), GE (5.1)	RF (13.2), PO (6.6), CH (5.3), GE (5.3), US (4.6)	RF (5.3), US (4.7), UK (2.2), GE (1.6), AU (1.3)	RF (2.2), US (2.2), TR (1.8), UK (1.3), LI (0.9)
			2016			
Number of articles	1379	739	387	165	846	131
Citation per article	1.33	1.07	7.31	1.76	0.58	0.27
Top 5 collaborating countries (% of Number of articles)	RF (17.2), US (6.4), CH (4.4), UK (4.2), GE (3.8)	RF (16.4), UR (5.1), US (4.6), CH (3.5), UK (2.4)	RF (12.9), US (12.4), UK (9.8), GE (5.2), UR (4.9)	RF (18.8), US (13.9), UK (8.5), CH (6.7), TR (6.1)	RF (10.8), US (2.1), UK (1.5), KG (1.2), PO (1.1)	RF (9.9), CH (1.5), UK (1.5), CZ (0.8), KG (0.8)
			2017			
Number of articles	1201	637	305	218	706	252
Citation per article	2.33	2.07	13.40	1.66	0.72	0.35
Top 5 collaborating countries (% of Number of articles)	RF (23.8), US (9.8), UK (5.7), CH (4.2), GE (4.2)	RF (19.6), UR (7.4), PO (6.6), US (6.4), CH (5.5)	RF (21.3), US (18.4), UK (9.8), IT (8.5), GE (7.2)	RF (24.8), GE (6.9), US (6.4), PO (6.0), UK (4.6)	RF (8.8), US (4.1), TR (2.5), UK (2.4), GE (1.4)	RF (9.9), US (2.4), TR (1.2), UK (1.2), GE (0.8)
			2018			
Number of articles	1377	754	395	209	863	266
Citation per article	2.37	2.93	10.58	1.76	1.17	0.94
Top 5 collaborating countries (% of Number of articles)	RF (22), US (9.7), CH (4.9), UK (4.9), GE (4.1)	RF (18.4), US (7.8), CH (4.9), SK (6.4), UK (3.7)	RF (19.2), US (17.7), UK (11.6), IT (9.1), FR (7.6)	RF (18.7), US (12.4), CH (7.7), TR (5.7), PO (5.3)	RF (8.7), US (3.8), UK (2.4), KG (1.5), TR (1.4)	RF (10.2), US (2.3), CH (1.5), ES (1.5), TR (1.5)

Table A1. *Cont.*

Characteristics	Natural Sciences	Engineering & Technology	Medical & Health Sciences	Agricultural & Veterinary Sciences	Social Sciences	Humanities & Arts
			2019			
Number of articles	1845	1085	462	275	873	301
Citation per article	2.55	2.80	5.06	1.75	1.41	0.56
Top 5 collaborating countries (% of Number of articles)	RF (25.3), US (7.5), CH (6.9), GE (4.7), UK (3.9)	RF (23.3), UR (7.1), CH (6.5), US (5.8), PO (4.9)	RF (21.6), US (16.5), IT (10.2), UK (9.1), GE (8.0)	RF (20.4), CH (8.0), US (4.7), GE (3.3), KG (2.9)	RF (15.3), US (4.2), UK (3.0), TR (2.5), CH (2.2)	RF (15), TR (1.7), ES (1.3), UK (1.3), US (1.3)
			2020			
Number of articles	2260	1340	674	330	988	239
Citation per article	2.51	3.06	9.01	1.76	1.63	0.77
Top 5 collaborating countries (% of Number of articles)	RF (24.8), CH (6.3), US (6.2), GE (3.7), PO (3.6)	RF (24.8), CH (6.3), US (6.2), GE (3.7), PO (3.6)	RF (17.7), US (9.1), IT (7.3), UK (7), GE (6.4)	RF (18.8), CH (8.5), US (7), GE (6.4), PO (5.2)	RF (14.8), US (5.6), UK (3.2), CH (2.3), UR (2.3)	RF (14.2), US (3.8), ES (1.7), EG (1.3), IT (1.3)

Note: In some fields of science and years, the number of collaborating countries did not reach five. For example, in Humanities & Arts in 2009, there were co-authors from two countries only (SK and US) who had publication co-authorship with co-authors from Kazakhstan. AR—Armenia, AU—Australia, AT—Austria, BE—Belgium, BG—Bulgaria, CA—Canada, CH—China, CZ—Czech Republic, DN—Denmark, ES—Estonia, EG—Egypt, FR—France, GE—Germany, GR—Greece, IT—Italy, KG—Kyrgyzstan, LI—Lithuania, MA—Malaysia, ND—Netherlands, NW—Norway, PA—Pakistan, PO—Poland, RF—Russian Federation, SK—South Korea, SW—Switzerland, SP—Spain, TR—Turkey, US—United States, UK—United Kingdom, UR—Ukraine, UZ—Uzbekistan.

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