Innovation and Technology Commercialisation Factors in Kazakhstan

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ABSTRACT
Commercialisation of research and development (R&D) results is a driver of increasing revenues and profits for companies, and it also has a positive impact on economic development, increasing global and national competitiveness in general. At the same time, commercialisation is a complex process, and its success depends on various factors. Therefore, this study aims to assess the mutual influence of R & D commercialisation factors in Kazakhstan with the identification and subsequent recommendation to strengthen the identified positive factors and level out the negative ones. The study used official data from the Bureau of National Statistics, such as the level of innovative activity of enterprises, the share of innovative products (goods, services) in GDP, the number of patents, R & D costs, costs of product innovation in industry, the number of employees performing R & D.

1. Introduction

Commercialization of research results has become an increasingly relevant topic in the world in recent years, as its goals are much broader than just making a profit from selling a scientific idea (Kumar et al., 2015). Commercialization of scientific developments can solve technological, economic, environmental and social problems of developed and developing countries (Gibson, 2014), thereby having a positive impact on company profits, increasing tax revenues, and enhancing global and national competitiveness (Sutopo et al., 2019). However, it is worth considering that the transfer of innovative ideas from the research laboratory through production, marketing and sales to the customer is a complex and risky task (Sung, 2009). The factors of commercialization of scientific research and development are by no means the same for all institutions, industries and countries.

The factors of commercialization of research and development (R&D) have been identified and discussed in many scientific papers. Among the above factors, the most frequently mentioned are the level of funding, the number of patents, human resources and innovation metrics (Karaveg, 2014). In Kazakhstan, the study of the factors of commercialization of the results of scientific, scientific and technical activities (a term introduced in the Law of the Republic of Kazakhstan "On the commercialization of the results of scientific, scientific and technical activities" in 2015) has not been conducted before. A study of the impact of public spending on R&D on various factors of commercialization of scientific developments revealed that public spending significantly affects such indicators as the number of employees in the field, the number of new technologies and technical objects created, the number of publications and citations (Alibekova, 2014). This conclusion is confirmed by the fact that the current system of R&D financing in Kazakhstan is characterized by a high level of public funding.

Due to the limited range of monitored indicators of innovation activity and commercialization of research and development results in Kazakhstan, the indicators monitored by the Bureau of National Statistics were used for this study: the level of innovation activity of enterprises, the share of innovative products (goods, services) in the gross domestic product (GDP), the number of patents, R&D costs, costs of product innovations in the industry, the number of employees performing R&D. Obviously, the indicators of innovation activity of enterprises are an important condition for the commercialization of the results of scientific and/or scientific and technical activities (RS&T), since innovation activity is recognized as the main factor of economic growth and competitiveness, which has a profound impact

on the development and commercialization of new technologies (Acemoglu et al., 2016). Public and business-funded R&D expenditures have a strong impact on the number of patent applications filed under the Patent Cooperation Treaty (PCT) system (OECD, 2018), which in turn generates commercial revenues since patents are an important factor and a harbinger of the possibility of commercializing R&D results. In turn, filing patent applications under the PCT system means that the commercialization of R&D results is reaching the international level, and they are aiming to enter global markets. Based on data from OECD countries, it is also advisable to take the expenditures of universities and businesses as a factor, since they have been found to positively affect revenues from technology exports (Alibekova, 2016).

Thus, this study aims to assess the mutual influence of R&D commercialisation factors (innovation activity, R&D and innovation costs, patents, and human resources) in Kazakhstan to identify and subsequently recommend strengthening the identified positive factors and levelling the negative ones.

Consequently, to achieve this goal, the concept, in particular the factors of R&D commercialization, was studied; methods for assessing the interaction of the selected factors were determined; the relationship between commercialization factors was analyzed; conclusions were drawn, and recommendations were prepared to enhance the positive impact of the identified factors.

2. Literature Review

Commercialization of R&D results is the process of accumulating knowledge, converting this knowledge into technologies, transforming technologies into products or processes, and bringing them to market for economic benefit. The definition of this term may vary depending on each country's laws and the research's objectives and results. However, the idea of commercialization is to develop a product concept before it is brought to market. In order to extract commercial benefits from research results, they must reflect a certain degree of social value and have the potential to increase the company's revenue. Below are definitions of the commercialization of scientific technologies as interpreted by various authors.

Table 1 Definitions of technology commercialisation

#	Authors	Definition
1	Chesbrough H.	Technology commercialization is the process of stimulating the use of all types of technologies, including internal and external ones, to improve the effectiveness of a company's innovation activities (Chesbrough, 2006).
2	Kim H.	Technology commercialization is the process of commercializing products, processes, and services using technologies to develop new products and improve existing products (Kim, 2009).
3	Wicaksana D.	Technology commercialization is a means of using technology obtained from research in production or consumer activities to generate profit from these activities (Wicaksana et al., 2019).
4	Kang J.	Technology commercialization is the process leading to production through the development of new products and processes with the actual use of R&D results or the improvement of existing products and processes (Kang, 2013).
5	European Commission	Technology commercialization is the process of bringing intellectual property (IP) to market for exploitation.
6	Choi J.	Technology commercialization is the process of bringing developed technologies to the market through commercialization (Choi et al., 2017).

#	Authors	Definition
7	Lee H.	Technology commercialization is a process associated with each stage of R&D aimed at acquiring ideas, improving them through complementation, producing products that can be commercialized and sold on the market (Lee et al., 2012).
8	Choi Y.	Technology commercialization is the actions and processes of creating new markets by adding ideas to developed technologies (Choi, 2019).

In general, the analysis of existing definitions allows us to conclude that commercialization of technologies implies the receipt of profit from the sale of a developed idea that can increase the competitiveness of a business and have a long-term effect on various sectors of the economy as a whole. In addition, the literature uses various synonymous interpretations regarding commercialization such as "commercialization of technologies", "commercialization of scientific technologies", "commercialization of R & D results", which, according to the authors, implies the process of promoting scientific developments to the market in order to obtain profit from sales and satisfy consumers.

As a review of previous studies on technology commercialization shows, the possibilities of commercialization of R&D are generally limited, that is, researchers focus on developing new technologies rather than on satisfying market demand (Karaveg, 2014). This fact is one of the reasons why commercialization of numerous R&D projects has not been successful. It is also worth considering that the nature of innovation itself is uncertain and difficult to predict, especially for radical innovations, which further complicates the possibility of their successful commercialization (Tidd & Bessant, 2009).

Regarding the positive factors of commercialization, Meinely (2001) argues that if the developed technology is transformed and applied to a specific product that will be successfully sold to various customers, then the commercialization process can be considered effective.

In the foreign literature, innovation metrics (Yun et al., 2018; Yung et al., 2022), the amount of financial support (Frederick & Kuratko, 2010, Smilor&Matthews, 2004; Lockett et al. 2003; Shane & Stuar, 2002), the presence of intellectual property protection (Vohara et al., 2004; Jungwook et al., 2009), the commercialization environment (Scholten et al. 2006, Sutopo et al., 2019; Egeln et al., 2003; Kriegesmann, 2020), and human resources (Somsuk et al., 2010; Karaveg, 2019) are mentioned as important factors in the effectiveness of commercialization.

Next, we consider specific factors that directly affect the efficiency of R & D commercialization. In particular, a direct relationship has been proven between innovation indicators and commercialization efficiency in the automotive, robotics and aviation industries, which means that the higher the innovative activity of an enterprise, the more effective the commercialization in these organizations (Yun et al., 2018). This result confirms that innovation indicators are important when assessing the success of bringing new products or services to the market (Cooper, 2008; Kusuma, 2015), and they are also assessed by the number of patents, R & D investment, product revenue and the speed of innovation implementation, where the highest indicators indicate high efficiency of R & D commercialization (Rogers, 2003). The export of innovative products is also noted as one of the factors reflecting the level of commercialization efficiency, where growing export indicators confirm high efficiency (Miller et al., 2011).

It is necessary to note the importance of human resources, expressed by the number of employees in the R & D sphere, which may include potential managers, internal experts, scientists, field experts and trainers, promoting effective commercialization of R & D (Somsuk et al., 2010).

Thus, if in foreign literature, the number of patents, investments in R & D, income from products, and the number of employees in this sphere were identified as the main factors influencing the commercialization of R & D, which were ultimately used to assess the effectiveness of commercialization, then in the works of domestic scientists the issues of assessing the factors of R & D commercialization have not been sufficiently studied. Also, given that the complex relationship between innovation and technology commercialization is crucial for politicians, industry practitioners and researchers seeking to promote innovative growth and market success, assessing the interaction of the above commercialization factors is of high priority.

3. Methodology

The research is focused on the descriptive analysis of various indicators of the dynamics of the development of science and commercialization of R&D in Kazakhstan over the past 20 years. In particular, the following indicators are considered: public expenditure from the budget on R&D (thousand tenge); the share of public expenditure in domestic R&D costs in Kazakhstan; the number of employees performing scientific research and development (thousand people); fees for the use of an intellectual property (billion dollars); the number of issued protection documents; the number of inventions filed through the Paris Agreement on Patent Rights (PCT) and the Eurasian Patent Agreement (EAPC); the number of new technologies and technical objects created and used; as well as the level of innovative activity of enterprises and the share of innovative products in GDP.

4. Results

Descriptive statistical data analysis allows us to study the development dynamics of R&D indicators in the Republic of Kazakhstan. Below are government expenditures on R&D in the Republic of Kazakhstan (Figure 1).

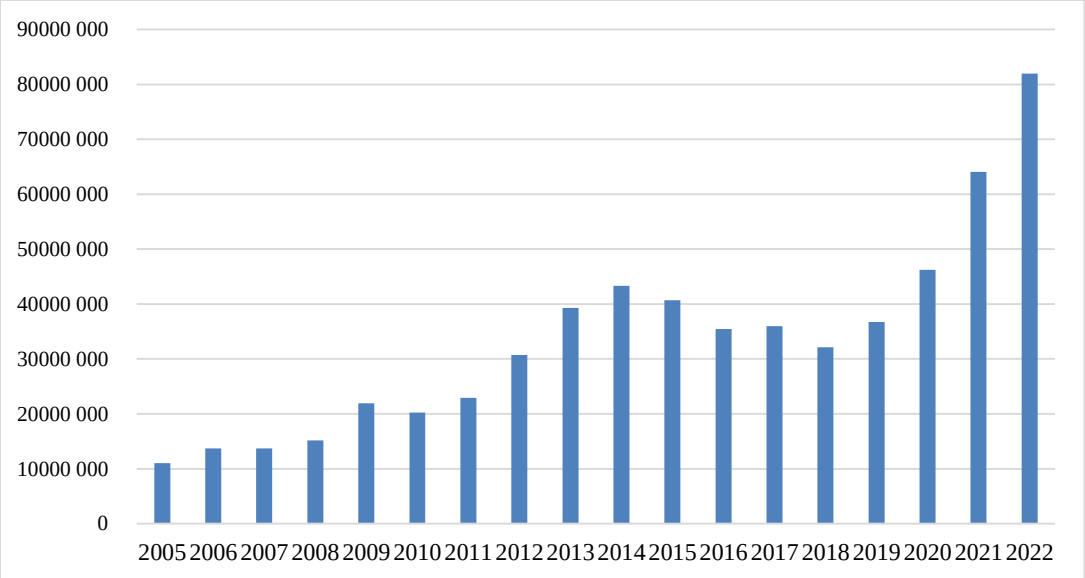

Fig. 2. State expenditures from the R&D budget for 2005-2022, thousand KZT.

According to the data presented in Figure 2, 2005 public R&D expenditure amounted to 11,015,579 thousand tenge, gradually increasing until 2014. In the following years (2015-2018), expenditures decreased approximately to the level of the beginning of the decade, which may be because, according to UN statistics (2016), global economic growth in 2015 was the lowest since the 2008-2009 financial crisis. Since 2019, there has been a stable increase in R&D expenditures. For example, over three years (from 2019 to 2022), the above expenditures increased by 55%, constituting the highest figure for the entire period, reaching 81,952,837 thousand tenge in 2022 compared to 36,716,126 thousand tenge in 2019. Such a stable growth in the state's funding volume indicates a high interest and initiative aimed at developing science and innovation in Kazakhstan.

The following figure presents data on government spending in domestic R&D costs in Kazakhstan for the period under study (Figure 3).

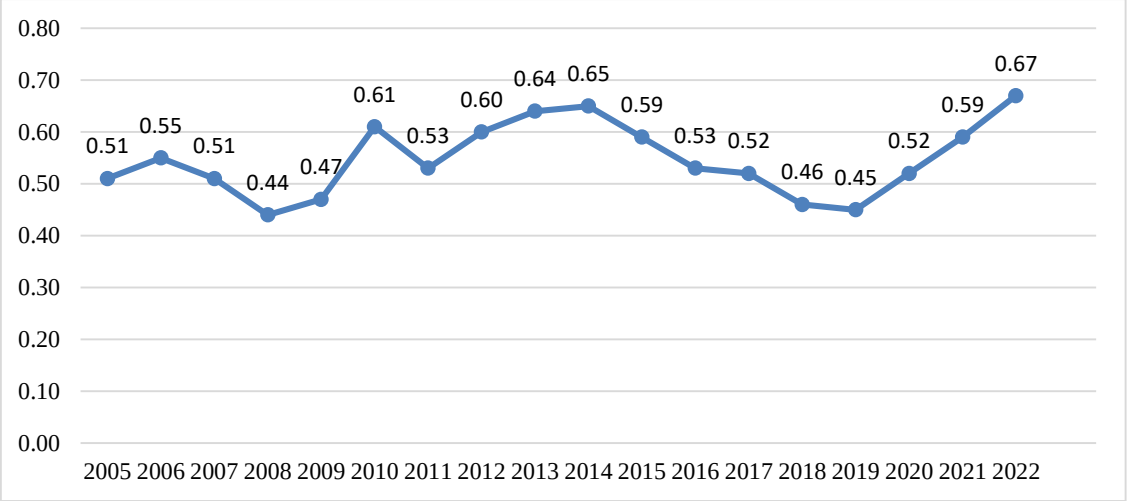

Fig.3. Share of government expenditures in domestic R&D expenditures in Kazakhstan for the period from 2005 to 2022

The share of public expenditure presented in the figure reflects the percentage of public expenditure on R&D to total domestic expenditure on this activity in the country. Over the entire observation period (from 2005 to 2022), the share of public expenditure in domestic R&D expenditure fluctuates between 0.44 and 0.67. It is clear that at the beginning of the period (2005-2010), the share of public expenditure was relatively low, but then began to increase, reaching a peak in 2022. The trend of increasing the share of public expenditure in R&D after 2010 may indicate more active government support and financing of research projects in the country. This may also be due to priority scientific areas, national development programs, as well as strategic goals of state policy in the field of science and innovation. The following figure presents the number of employees engaged in research and development for the period from 2005 to 2022 (Figure 4).

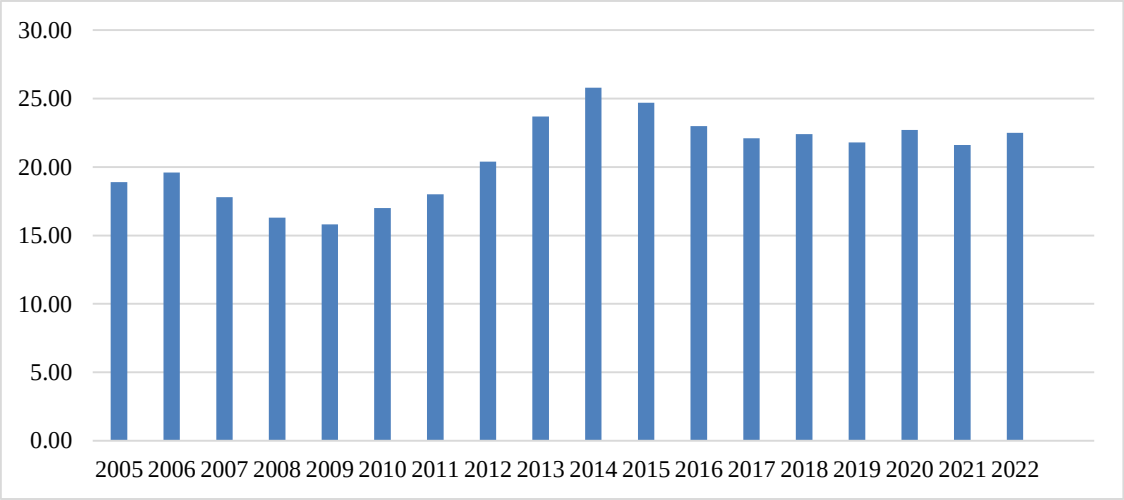

Fig.4. The number of workers who carried out scientific research and development in the Republic of Kazakhstan for 2005-2022

According to the data in Figure 4, from 2005 to 2013, there was a steady increase in the number of employees engaged in scientific research and development. During this period, the number increased from 18.90 thousand in 2005 to 23.70 thousand in 2013. After 2013, there was a slight decline in the number of employees. This decline, however, was not as significant as the growth before that time. The maximum number reached in 2014 was 25.80 thousand employees. From 2014 to 2022, the

number of employees fluctuates, but the overall trend remains relatively stable. From these data, it can be concluded that there was a significant increase in the number at the beginning of research activities, possibly associated with an increase in funding or interest in scientific research. After peaking in 2014, the number has stabilised at a relatively high level, and growth is expected due to increased funding in this area and the state's strategic goal of increasing R&D funding as a share of GDP to 1% by 2030.

Below are data on the use of intellectual property in terms of export revenues and import payments from 2005 to 2022 (Figure 5).

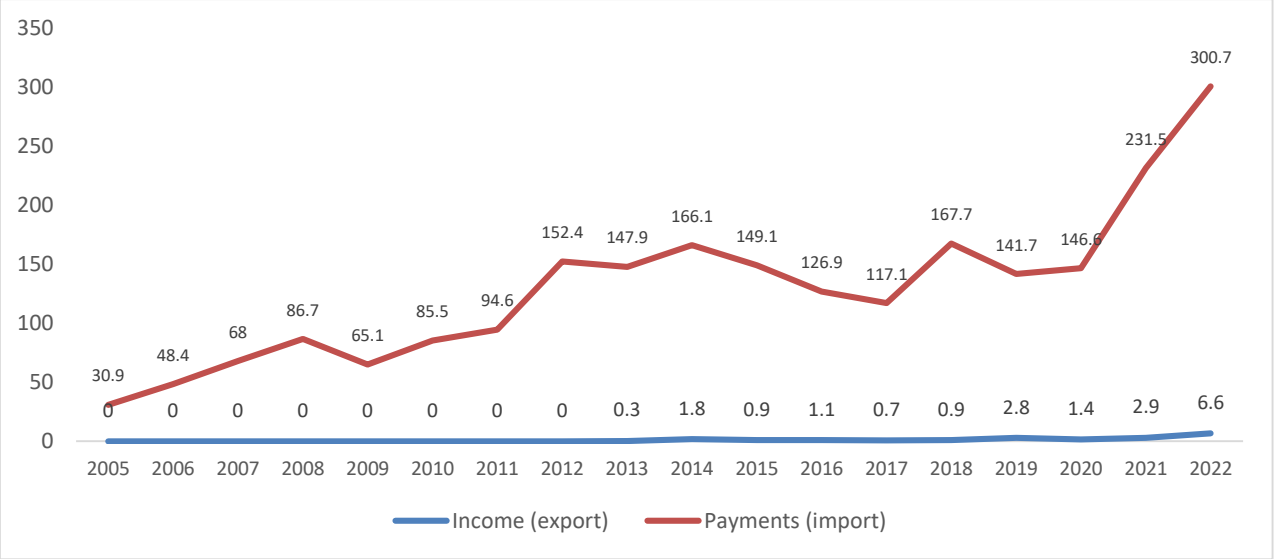

Fig.5. Payment for the use of the intellectual property for 2005-2022, billion dollars

According to the data presented in Figure 5, during the period under review, export revenues varied from zero at the beginning to a significant increase towards the end. While there was no export revenue in 2005, it increased to 6.6 billion in 2022.

Import payments increased over time, starting from $30.9 billion in 2005 to $300.7 billion in 2022. This may indicate an increase in imports of goods and services during the period. Intellectual property fees are also presented in the table. These payments started at zero until 2013, after which they increased, reaching $6.6 billion in 2022.

Overall, the data show an increase in export revenues and import payments, as well as the adoption of intellectual property in foreign trade, during the period under review. If we delve deeper into the statistics of individual types of intellectual property, the detailed data are presented below in Figure 6.

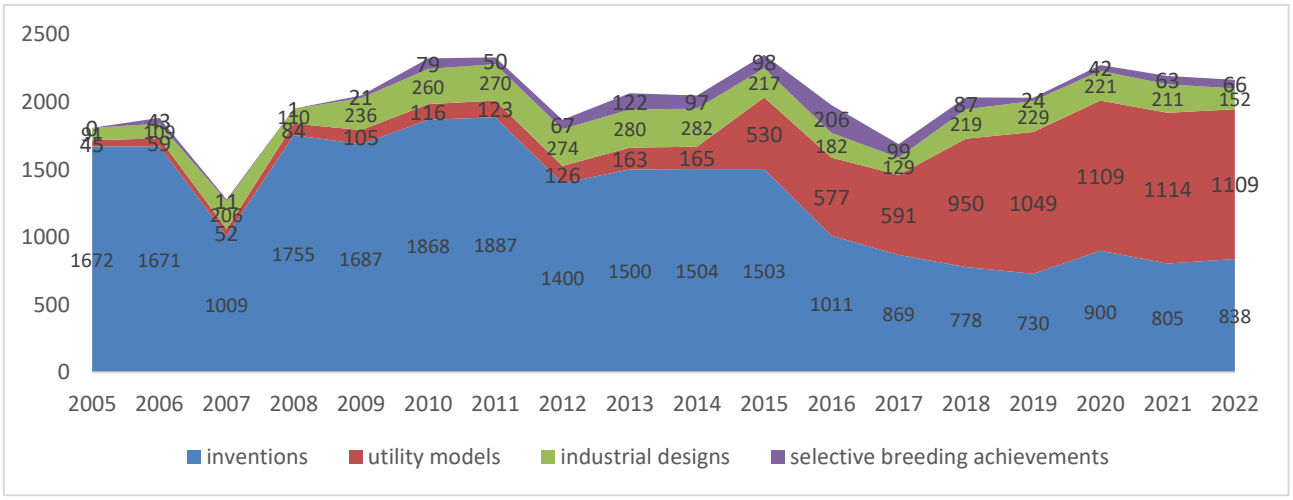

Fig.6. Statistics of issued security documents for 2005-2022.

As can be seen from Figure 6, the total number of patents varies from year to year in each category. The peak in the number of patents for inventions was in 2010, and then there was a general downward trend. The number of patents for utility models and industrial designs also has spikes in different years, but the overall trend is rather upward. The number of selection achievements is comparatively smaller compared to other categories, but has tended to increase in recent years. The following figure presents data on domestic inventions filed through foreign organizations (Figure 7).

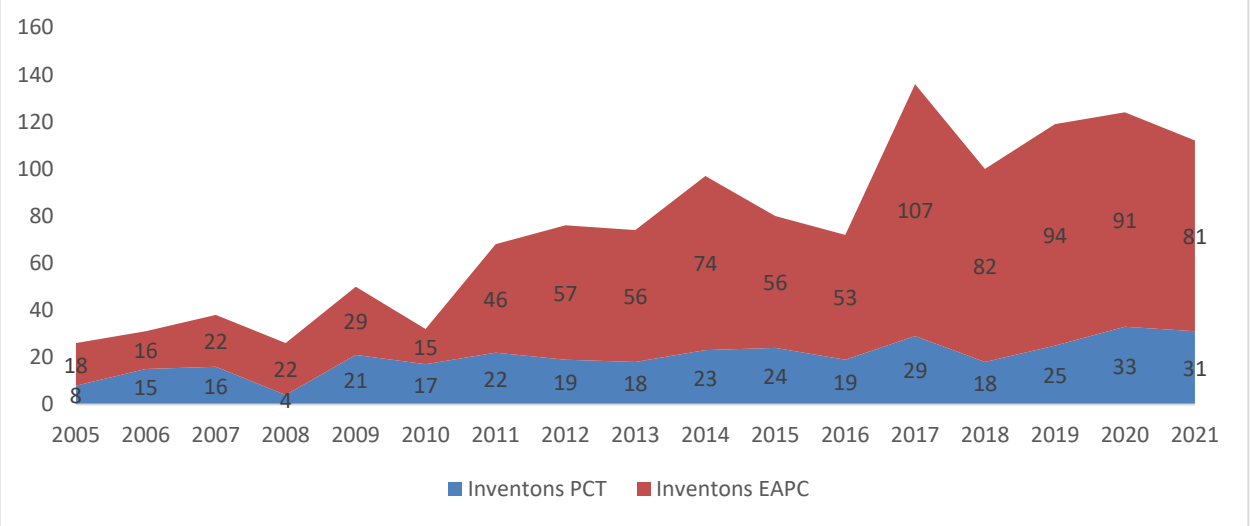

Fig. 7. Number of inventions filed through the Paris Patent Rights Agreement (PCT) and the Eurasian Patent Agreement (EAPC) from 2005 to 2021.

Thus, in 2005, 8 inventions were filed through the PCT and 18 through the EAPC. The number of inventions gradually increased in both cases until 2014, when 23 were filed through the PCT and 74 through the EAPC. After 2014, the number of patents filed through both agreements fluctuated again but generally remained high.

The maximum number of inventions through the PCT was registered in 2021 - 33, while through the EAPC - in 2017, when 107 inventions were filed. In general, the data show a tendency towards an increase in the number of patents filed during the period under review, with some fluctuations in individual years. The increase in the number of patent filings through the PCT and the EAPC indicates that Kazakhstani companies and innovation centers are actively participating in international programs and initiatives in the field of intellectual property. The number of new technologies and technical objects created and used is presented below (Figure 8).

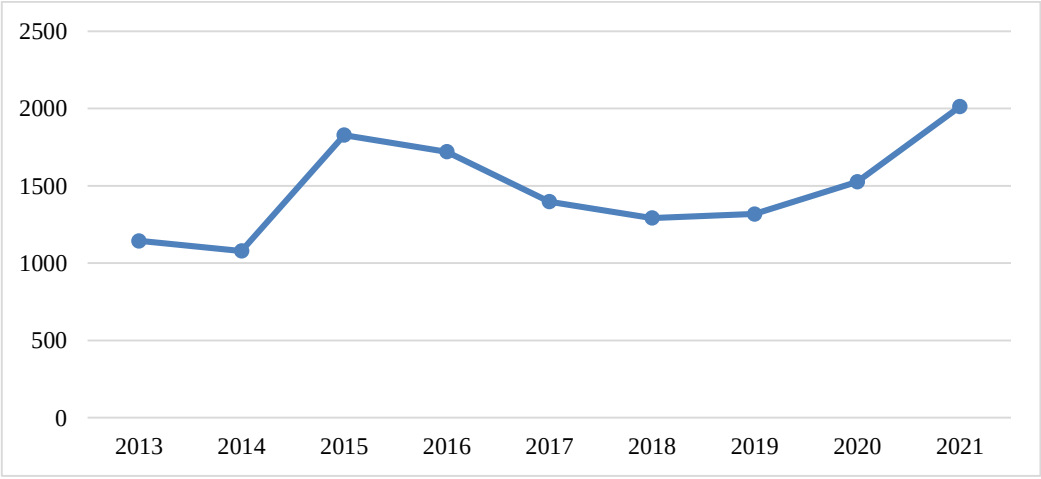

Fig.8. Number of new technologies and technical objects created and used in the period from 2013 to 2021

According to Figure 8, at the beginning of the period, in 2013, 1,144 new technologies and technical objects were created. There is some variability in the subsequent years: in 2014, this number dropped to 1,079, then in 2015 it increased sharply to 1,828. However, in 2016, it decreased slightly again to 1,721.

From 2017 to 2021, the number of new technologies and technical objects created continued to fluctuate, but overall maintained a downward trend: from 1,398 in 2017 to 2,012 in 2021. These data may indicate various factors influencing innovation activity in certain areas, such as economic conditions, scientific discoveries, changes in consumer demand, and others. Below is the dynamics of the level of innovative activity of enterprises and the share of innovative products in GDP for the period from 2005 to 2022 (Figure 9).

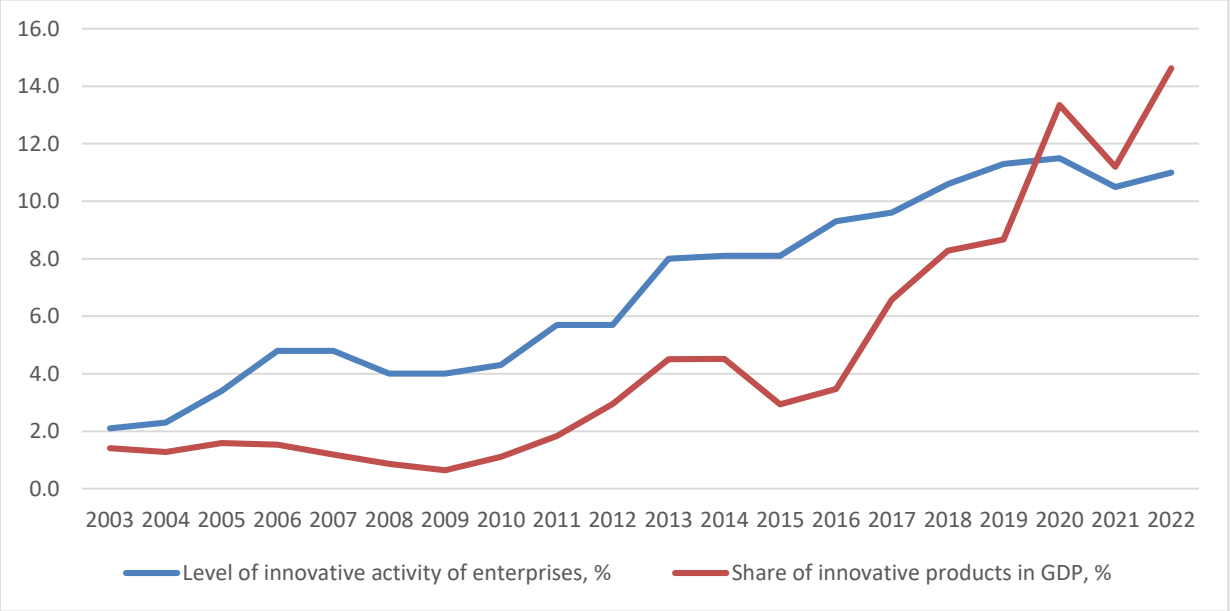

Fig.9. Level of innovative activity of enterprises and the share of innovative products in GDP for the period from 2005 to 2022, %

According to the data presented in Figure 8, the level of innovative activity of enterprises increased from 2005 to 2013, starting from 3.4% and reaching 8% by 2013. However, in the period from 2014 to 2022, this level remained quite stable, fluctuating between 8.1% and 11.5%.

The share of innovative products in GDP also increased slightly from 2005 to 2008 and then decreased to 0.64% in 2009. After that, a gradual increase began, and from 2013 to 2022, the share of innovative products increased significantly, reaching 14.62% by 2022. It is important to note that this trend indicates an increase in innovation's contribution to the country's economy.

5. Conclusions

In general, given that the development of R&D and its commercialisation in Kazakhstan is a key aspect of the strategy for modernising the economy and ensuring sustainable growth. Statistics show that in recent years, the government has sought to create favourable conditions for the development of innovative start-ups and high-tech industries by simplifying patent procedures and increasing funding and incentives for investors in science and technology. However, despite the progress, Kazakhstan still faces challenges, such as the need to improve the quality of scientific research, attract talented specialists and expand access to modern technologies.

Therefore, in the context of global challenges, identifying the factors of commercialization of research and development (R&D) plays a key role in understanding the processes of innovation and their impact on economic growth and development. The commercialisation of R&D is a powerful catalyst for

economic growth. Translating scientific research and technological developments into commercially successful products and services contributes to an increase in production, investment and employment, which ultimately contributes to an increase in GDP and an improvement in well-being. Enterprises that successfully commercialize the results of R&D gain a competitive advantage in the market. This allows them to create unique products and services that meet consumer needs and ensure a stable position in the market. Commercialisation of R&D contributes to technological progress in various sectors of the economy. New technologies and innovative products increase production efficiency, reduce costs, improve life quality, and help solve social and environmental problems. Successful commercialisation of R&D attracts interest from investors. This contributes to the inflow of capital into innovative projects and the development of the scientific and technological sectors. The commercialisation of R&D contributes to the growth of the scientific base and human resources development. Successful innovations attract talented researchers and specialists and stimulate investment in scientific and educational institutions.

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