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Article

Holistic Approach to R&D Products' Evaluation for Commercialization under Open Innovations

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Abstract: A holistic approach to R&D products' evaluation for commercialization under open innovations is developed. The approach is tested on the example of the device of the interferometric determination of the refractive index of crystalline materials in the optical range. The proposed approach will allow setting a price that will satisfy all the parties of a transfer agreement with a higher level of accuracy and will meet market requirements. Unlike popular methods of evaluating the R&D product, a holistic approach will, on the one hand, be based on the actual costs and the break-even level of a R&D product and, on the other hand, will determine how much the consumer is receptive to a R&D product, and, then again, will show how the added value of the product will develop under the influence of market effects. It is noted that the application of a holistic approach to R&D products' evaluation for commercialization should be supplemented by assessing the willingness of potential customers to purchase this R&D product at a specific price. It is proved that the proposed holistic approach to R&D products' evaluation for commercialization is multifunctional. The approach can be applied to different types of economic activity, R&D products, and types of markets. The obtained prices based on the application of a holistic approach to R&D products' evaluation for commercialization and the results of marketing research of the interferometry market testified to potential prospects of the commercialization of a R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range and its long-term competitiveness. Based on the results, the key provisions of the concept of providing competitive benefits for the period of implementation of the analyzed R&D product are identified. Taking into account fundamental elements of the open innovation paradigm underpins the authors' holistic approach.

Keywords: R&D products; holistic approach; commercialization; open innovations; evaluation

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1. Introduction

The global expansion of the open paradigm innovation suggested by H. Chesbrough (USA) provided grounds for the interactive collaboration between the business and science in the R&D sphere, which leads to the significant increment of effectiveness of innovative product commercialization in any phase of development—from an idea to an experimental prototype. The philosophy of open innovations has become a driving force for the emergence of numerous scientific and business schools, which, in turn, have caused a number of new approaches to generating a market launch and the diffusion of innovations. However, contemporary prospects and challenges stipulated by the fourth Industrial Revolution affirm the necessity for the revision of one of the open innovation paradigm's basics—methodologies for economic evaluation, which would take into consideration the volatility of an external environment, as well as globalization and intellectual processes in the world. Forming methodological approaches to the economic evaluation and management of the R&D products' commercialization is among those important issues.

The acceleration of a life cycle characteristic of most modern technological innovations, a significant level of market convergence, the synergy of technologies in increasing competition, and other factors indicate the feasibility of developing a comprehensive approach to evaluating R&D products for commercialization. Such an evaluation should take into account, on the one hand, the level of novelty and the degree of technological readiness for the commercialization of a R&D product and, on the other hand, how much the consumer is receptive to it, and, then again, how the added value of the product will develop under market effects. Taking into account these components will allow setting prices for R&D products with a high level of accuracy and compliance with market demands. The difficulty of such an evaluation is to find, develop, or combine known evaluation methods in a changing market. At the same time, the need to evaluate R&D products for commercialization is growing at a much faster pace than the emergence of appropriate methodological developments.

1.1. General Literature Review of the Research Problem

The relevance of a comprehensive approach to the evaluation of R&D products is evidenced by the analytical data of the World Economic Forum [1] (p. 39). According to the Global R&D Funding Forecast, the main challenges for R&D in 2021 are economic factors, in particular: economic disruptions (53%), increasing costs (46%), and insufficient budgets (49%) [2] (p. 28). The situation is similar to R&D for the production of new technologies, where such factors include: the economy (48%), R&D funding (49%), and time to market (28%) [2] (p. 29). These data actualize the problem of the economic evaluation of R&D products, which covers all the above elements of R&D products during the evaluation for commercialization.

The relevance of the commercialization of R&D products increases with their development and growth in the market. In particular, according to the data [3], in 2021 more than USD 2.4 trillion will be invested in R&D labs, academic research centers, and other organizations (more than 115 countries around the world), which is a much higher figure compared to previous years. In particular, according to [4] (p. 5), in the USA, in 2021 there was an increase in the number of R&D products by 3.2%. Despite the pandemic caused by COVID-19, the OECD report [4] (p. 3) states that most large R&D investors sustained R&D during the crisis.

The importance and relevance of evaluating R&D products are demonstrated in the studies [5–10] where scientists propose a variety of decisions that focus on social, technological, environmental, marketing, financial, and other characteristics of innovative products that are being prepared for commercialization.

Some scientists divide the innovation process into separate stages, which are economically evaluated, for example, at the stage of R&D and commercialization [11]; the others [12,13] evaluate R&D products based on their complexity. However, in these studies, the authors did not aim to aggregate the evaluated aspects of the R&D product into an indicator or a group of indicators that would be useful for commercialization conditions.

The researchers [14] believe that most commercialization processes fail due to the ineffective assessment of the chances and risks of developing R&D products at each stage of the process. A similar opinion can be traced in the study [15], where the authors develop a decision-making model based on technology transfer assessments. In addition, these assessments can be used to determine the technology transfer potential. This allows organizations to develop a portfolio of technologies effectively. The scientists [16] substantiated the mixing of methods, which is based on the evaluation of the text. They proposed 154 performance indicators for innovative products.

From the point of view of the problems raised in the article, it is important to determine the strategic consequences of the using of investment models for R&D products, formed in [17]; in [18]—a methodical approach based on Nash equilibrium, the authors propose to apply the approach to R&D in the case of non-cooperative oligopoly; in addition, scientists note the vague uncertainty of market shares and information; in [19]—scientists substantiated the signs and approaches to coordination resources of innovative products of a high level of complexity. In [20], the applications of a neural network methodology and a Monte Carlo method of least squares were combined. This is important for assessing the investment opportunities of R&D products.

In part of the works of the subject sphere, the methodical tools on the economic evaluation of R&D products in the context of the system of their transfer and commercialization are offered. In particular, the study [21] shows a model for measuring the effectiveness of Chinese innovation between different elements of the innovation infrastructure. Scientists use a dynamic measurement of network vulnerabilities. A systematic approach to the development of applied tools is outlined by scientists [22], who proposed the R&D platform and the method of evaluation index of the R&D platform, which will facilitate the transformation of R&D results. In the study [23], scientists substantiate the structural factors that determine the capabilities of the subjects in terms of R&D. To do this, scientists use data analysis methods with all the necessary attributes. In [24], authors offer ideas for the research policy of Chinese IEDS. These suggestions can be useful while evaluating the market environment to which R&D products are planned to be transferred, but they are based on the already evaluated internal structure of the R&D as the production process. Analyzing the influence factors on efficiency in open R&D by the Tobit model in [25] is presented. A new approach to the assessment of R&D projects based on IVIF AHP and fuzzy axiomatic design is given in paper [26].

Some works contain cases on the commercialization of R&D products in specific countries. For example, researchers [27] argue that identifying different barriers and understanding their interrelationships will provide a better understanding of the complex nature of the technology transfer process by Philippine universities, which can be seen as contributing to important decision-making initiatives. Cognitive cases about the effect of government R&D subsidies on firms' innovation in China were developed in [28]. Local Japan R&D support as a driver of network diversification in [29] is presented, the main catalysts for collaborative R&D projects in the Dubai industrial Sector—in [30], performance drivers of the R&D activities in the chemical sector in Spain—in [31], the research on the influence of R&D human resources on innovation capability (the empirical research on GEM-listed enterprises of China)—in [32]. Innovative, scientific, and technical activities in Ukraine in the context of the commercialization of R&D are described in [33–35]. However, most authorial approaches, methods, and models describe solutions for a specific problem situation, enterprise, or industry. For example, the main idea of the scientists in [36] is to create a methodology that would improve the pre-selection of innovative projects in regulated organizations. In [37], it is proposed to evaluate R&D products based on a combination of evaluations of R&D activities and investments of pharmaceutical companies and the views of participants on R&D. The paper [38] analyzes how innovation performance feedback affects firms' decisions to change the diversity of their technological alliance portfolio and how this relationship is moderated by firms' R&D intensity.

The sectoral aspects of the evaluation of innovative technologies are presented in many scientific articles, for example: in information technology, biotechnology, and biopharmacy—[39,40], and utilities—[36]. The paper [41] estimates innovative technical efficiency, the output elasticity of R&D inputs, the factor-biased indicators of technological innovation, and the elasticity of substitution between R&D inputs. Ways to alleviate R&D resource misallocation are discussed based on these indicators.

Scientific papers [42–45] present the R&D analysis in the context of the open innovation concept.

The scientists in [46] evaluated and compared the results of R&D in several Asian countries. These countries were divided by researchers into groups based on marginal costs (1% of GDP on R&D). Using a result-oriented DEA model the authors identified the countries that are at the limit of efficiency. They detail a number of parameters which determine the effectiveness of the R&D process.

The publications present the results of research on the specific aspects of the evaluation of R&D products. For example, scientists [47] draw attention to the importance of the compliance of R&D products with social priorities, which will affect their funding and further commercialization. Scientists characterize financial instruments for the substantiation of innovative projects. Fundamental in this are the combination of goals and motivations of public action and RFOs. The scientists [48] examined the relationship between R&D investments and firms' economic value.

Many world scientists and practitioners have paid attention to this issue, which testifies to its unconditional relevance. However, despite the numerous developments of scientists and practitioners, a comprehensive holistic approach to the evaluation of R&D products for further commercialization has not been developed yet. There is no universal approach that would take into account both the sectoral signs of R&D products and market specifics.

The importance of such research is highlighted in the documents of the World Economic Forum, where the top antecedences for the revival of the economy will be directing innovation and technological diffusion [1] (p. 41), which requires an appropriate methodological basis.

1.2. Substantiation of Hypotheses

The literature review outlines that scholars have not yet drawn up methods and models, which would enable the comprehensive evaluation of a R&D product in order to commercialize it. Particularly, there is a need for methodical guidelines, which would help to form a price range appropriate for a certain R&D product under a certain market situation. Such a range may be an outcome of combining the income, cost, and comparative methodical approaches. Nevertheless, the existing methodical achievements disclosed in the literature do not contain such idea.

We state that combining the above mentioned three evaluation approaches will allow taking into account factors, which are usually taken into consideration for such an evaluation, as well as their reciprocal correlation. For instance, applying the comparative methodical approach, scientists focus on evaluating market factors. Simultaneously, these factors are considered in applying the income approach to a lesser extent because they may explain values of other factors being inherent to applying the income approach. Taking into account moments, which are concerned with the intersection of factors in the process of evaluation, enables forming a price for a R&D product with high precision and accuracy.

Particularly, evaluators often leave out of the account the reciprocal interaction of some factors in applying only one or two methodical approaches. Therefore, we should highlight several factors among the aforementioned ones:

- the level of product novelty;
- the extent of the technological readiness of a product (also, the level of elaborating a marketing complex regarding its market launch);
- the level of consumer perception of a product;
- the level of product competitiveness;
- the level of a product's influence on ecology;
- the level of product commercialization riskiness;
- the prognostication of the market diffusion of a product;
- the prognostication of the manifestation of the added value embodied in a product under the market impact (convergence, spillover effects, multiplying the product value, etc.).

Obviously, both value and cost factors participate in such an evaluation. To perform such an evaluation, we should apply a complex evaluation approach—the holistic approach.

The holistic conception is based on the integrity of different factors through their aggregation by a particular purpose. Scientists apply the holistic approach in various research fields when they encounter large sets of data characterized by complicated reciprocal correlations. For example, in the field of economic evaluation, the holistic approach was applied by a number of scientists [49–52]. Within the scope of the study of scientists [53], the holistic approach enabled them to prove the effectiveness of the novel conception for knowledge management conclusively. The book's authors in [54] substantiate managerial decisions, relying on the holistic approach.

The essence of the holistic approach contemplates considering interrelations between entities as a system where each component influences its efficiency. The expediency of such an understanding and the use of this approach in the field of economics and management are substantiated in several scientific papers [55–57].

Scientific works [58–61] present the holistic approach in the context of the open innovation concept.

This problem updated with statistics and confirmed by the work of scientists and practitioners determined the purpose of this study—to justify a holistic approach to R&D products' evaluation for commercialization.

The aggregation of different aspects of the economic evaluation of a R&D product for commercialization will allow balancing its value and cost indicators. In turn, this will contribute to the effective commercialization of R&D products, as this process will take into account the specific elements characteristic of the R&D product in the relevant market in a particular situation with consumers.

The hypotheses are formed to achieve this goal.

Hypothesis 1. *The comprehensive application of known holistic approaches to the evaluation of the R&D product for further commercialization will allow setting a price that will satisfy all the parties of a transfer agreement with a higher level of accuracy and meet market requirements.*

Hypothesis 2. *The obtained prices fully satisfy all the conditions necessary for effective commercialization and the market launch of the R&D product.*

The importance of formulating and substantiating the aforementioned hypotheses consists of the following assumptions:

- a need for obtaining a more precise result of evaluation, which will allow substantiating competitive positions of a R&D product (***Hypothesis 1***);
- a range of prices for a product will foster the maneuverability of managerial decisions concerning further sale of a product by a customer (an investor, etc.) (***Hypothesis 1***);
- an opportunity for the prognostication of rather difficult phenomena, which may happen in relation to a product in a market after its commercialization (the diffusion, convergence, spillover effects, multiplication of the product value, etc.) (***Hypothesis 1, Hypothesis 2***);
- an opportunity for maximal attention to all requirements and terms of planned commercialization and a market launch of a product in the phase of product evaluation (***Hypothesis 2***);
- an opportunity for obtaining a set of analytical data and conclusions, which will be helpful for specialists of a substantive area and also in the area of a certain product chosen for evaluation (***Hypothesis 1, Hypothesis 2***);
- substantiating the expediency/inexpediency of applying the holistic approach to the economic evaluation of R&D products in order to commercialize them (***Hypothesis 1, Hypothesis 2***).

Proving or refuting hypotheses will make it possible to form a methodological basis for evaluating a R&D product for commercialization, which can be applied in different industries and for different types of R&D products.

2. Materials and Methods

2.1. Methods Applied in the Research

The cost, comparative, income, and combined methodological approaches were used to conduct this study.

The cost methodological approach. The main rule for evaluating a R&D product according to this approach is to achieve an equilibrium price. The approach is based on calculating the amount of money that will compensate the developer of the R&D product for the future profit on the basis of owning it. The methods of the cost approach allow setting the price of the R&D product quite accurately. Mostly, this approach is applied to non-profit R&D products that are unique and/or non-marketable.

The cost approach is useful when adding a R&D product to an entity's balance sheet, which will significantly increase the entity's market value. The calculation of the price in this case is less risky, compared to other approaches, because it is based on the determination of the real costs. Such a price for a R&D product never corresponds to its market price; the future benefits of using the R&D product are not taken into account; there are difficulties in calculating the depreciation of the R&D product; there are often problems with the discrepancy between the cost of creating a R&D product and the cost of reproducing the product (developing a new R&D product is cheaper than renovating an existing one).

Applying methods of the cost approach in drawing up the declared holistic approach, it is important to choose such methods rigorously, as well as to understand what type of essential information each of them will foster to acquire in the future. Analysis of contemporary achievements of scholars regarding the cost approach shows that methods of this approach may become the basis for numerous managerial decisions, particularly in the process of forming amounts of product sales grounded in principles of price elasticity.

The scholars in [62] dedicated their scientific paper to examining the methodology for forming and evaluating costs. They considered a category of costs from the standpoint of fundamental research. This study provided the integral perception of both transactions in costs and the prognostication of costs.

The scientific paper [63], which outlines the conclusion regarding the choice of prospects and approaches to the cost calculation, deserves special attention. The scientific papers [64–66] and other scholars thoroughly considered the cost approach.

The comparative (market) methodological approach to valuing a R&D product allows estimating the market value (or setting the market price) by analyzing similar R&D products. However, transfer agreements with comparable R&D products are usually limited to a few companies, and prices are trade secrets. Due to the specifics of R&D products, it is often very difficult to find market analogues for them, and sometimes it is impossible.

Authors of the scientific papers [67–69] describe the methodology of the comparative approach. The scientists in [70] apply this approach in a plane of markets of various countries, while the scientists in [71]—as an element of modeling, [72]—base their approach on the principles of applying machine learning models. Applying the comparative approach is popular in papers from different areas of activities, primarily owing to an opportunity for dealing with real data of a market environment.

The evaluation of R&D products by a comparative approach makes it possible to take into account the dynamic nature of the price of innovative products. At the same time, the comparative methodological approach is not popular (most of the innovative products are the only ones). The advantage of this approach is the ability to take into account the current supply of and demand for R&D products; however, it is extremely difficult to find information about competitive counterparts; the concept of comparability between analogues is often criticized; such an approach is possible only if there is a variety of information not only about the evaluative R&D product, but also similar objects, etc. Evaluators must justify adaptations to both the final value of the price and the intermediate calculations.

The income methodological approach allows for estimating the value of a R&D product as a current value of future income related to owning the R&D product over its expected useful usage. According to this methodological approach, price indicators are determined based on the present value of forecasted future benefits. The choice of income approach methods will depend on the type of product, the characteristics of income, etc. The main idea of using this approach is the user's desire to obtain additional income from their production (receiving additional resources through the use of R&D products), which will be part of its total income.

In many cases, this approach is universal, but its "bottleneck" is the inability to obtain the necessary information to evaluate innovative products.

Methods of the income approach are mainly applied for predicting a situation and modeling future decisions. The income approach has been used by the scientists [73–76] as an element of applied methodologies.

The combined methodological approach to the evaluation of R&D products integrates cost, comparative, and market approaches. Given that R&D products are mostly innovative products, the specifics of industries, and the conditions of their development and application, in practice it is necessary to evaluate R&D products using several methodological approaches, comparing and aggregating the results.

The above approaches are described in more detail, with elements of practical nature and phased application in the Results section, on the example of the R&D product used for this study.

Aggregating the cost, comparative, and income evaluation approaches in this scientific paper allowed for forming the holistic approach to evaluating R&D products for commercialization and a market launch. An idea of applying the holistic approach is grounded in the methodology of systems: each element of a system makes an individual contribution to efficiency indicators of the system, but these contributions stipulate a significantly higher effect together than apart. Nowadays, this approach is popular in various areas of activities. Although this fact is confirmed by papers of several researchers [77–80], the approach is only used as an instrument for addressing a local problem. However, owing to its complexity, the holistic method conduces to solving strategic problems. Since pricing is a strategic issue (this assertion can be particularly confirmed by the functions of price—rationing, distributive, and incentive ones, etc.), applying the holistic approach to pricing aims at providing a substantiated response to questions raised in this article.

2.2. Materials and Procedures of Research

To reach this goal, the following scientific and methodological approaches are used: systematic—to evaluate the R&D product to commercialize the current methodological approaches (cost, income, comparative); generalization, grouping, and systematization—for the study of competitive analogues of the evaluated R&D product, as well as for the implementation of the income approach; abstract and logical—to develop the concept of ensuring the competitive advantages of the R&D product; retrospective analysis—to study the types of work and costs for the development of the R&D product; comparative method—to compare R&D products—competitive analogues; structural and logical analysis—to determine the relationship between the competitive advantages of R&D products—analogues; statistical analysis—to compare the state and prospects of the technological development of R&D products and determine the relevance of the issues of this work; methods of analysis/synthesis—to study the essence of the evaluated R&D product; graphic—to illustrate the analytical and methodological material and the results of the study.

Drawing on methods of case study, contemporary theories, and economic practices, we substantiated the holistic approach. To substantiate the conclusions by the hypotheses, the evaluation of the R&D product in the field of interferometry is performed.

3. Results

The research was carried out on the example of the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range. To prove the hypotheses, the following actions were performed: (1) technical and economic evaluation of the R&D product; (2) marketing research of the R&D product market, including those market segments that were distinguished for its commercialization (in the sectoral and geographical sections); (3) cost evaluation of the R&D product based on an integration of the methods of cost, comparative, and income holistic approaches; (4) formation of the concept of providing the competitive advantages of the R&D product based on the received estimated figures.

3.1. Technical and Economic Evaluation of the R&D Product of the Interferometric Determination of the Refractive Index of Crystalline Materials in the Optical Range

3.1.1. Purpose and Types of Interferometers

An interferometer is a tool used in various fields of activity, numerous industrial and research programs, which allows measuring the quality parameters of products (including in particular: optical components, cameras, laser printers, machined parts, etc.). Interferometers can be used to measure many physical parameters.

There are different types of interferometers: Fizeau, Mach−Zehnder, Michelson, Fabry−Pérot, Sagnac, Fiber, Twyman Green, common path, etc. In addition, interferometers are classified by the field of application, end-use, and geographical features.

3.1.2. Output Technical and Economic Parameters of the Studied R&D Product

The technical and economic parameters of the studied R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range are given in Table 1.

Table 1. Technical and economic parameters of the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range [1].

Parameters	Information by Parameters
R&D product	Technology of the interferometric determination of the refractive index of crystalline materials in the optical range.
Developers of the product	Laboratory of the Innovative Research and Training Center of Nano-Engineering of Lviv Polytechnic National University, Ukraine (Andrushchak and Karbovnyk [81]).
Application sphere	The author's interferometer can be used in the fields of astronomy, micro-nidrodynamics, oceanography, measurement of mechanical voltage/deformation, fiber optics, spectroscopy, seismology, nuclear physics and particle physics, velocimetry, and optometry, medicine, etc.
Priority areas of industry	Optics, telecommunications, lasers, spectroscopy, surface topography, geodesy, television holography, etc.
Type of the interferometer used in the author's product	The Michelson interferometer.
Industry trends	R&D product development corresponds to: • programs for the realization of Ukraine's national interests in the Euro-Atlantic direction (processes of improving the modern international security architecture); • integration of the Ukrainian telecommunications industry with the EU market; • development of state regulation and scientific and technical support of the telecommunications industry, raising domestic standards, etc.; • programs of technological re-equipment and modernization of the system of the national medical branch, defense branch, etc.; • development of innovative technologies taking into account competitiveness trends, etc.
Evaluation of the product novelty	The R&D product has no analogues in Ukraine; in some respects, it exceeds the world level.
Scope of commercial interest in the product	Sectoral, national importance.
Protection of the product by intellectual property rights	Patents of Ukraine: №94390; №93863; №69582; №39155; №35224.

[1] Source: made up by the authors based on the results of their research.

3.2. Market Research of the R&D Product of the Interferometric Determination of the Refractive Index of Crystalline Materials in the Optical Range

3.2.1. World Market

The total market of interferometers is projected to be segmented by regions (and countries of major industry operators) by 2028: North America (the United States, Canada, Mexico), East Asia (China, Japan, South Korea), Europe (Germany, the UK, France, Italy, Spain, the Netherlands, Switzerland, Poland), South Asia (India, Pakistan, Bangladesh), Southeast Asia (Indonesia, Thailand, Singapore, Malaysia, the Philippines, Vietnam, Myanmar), Middle East (Turkey, Saudi Arabia, Iran, the United Arab Emirates, Israel, Iraq, Qatar, Kuwait, Oman), Africa (Nigeria, South Africa, Egypt, Algeria, Morocco), Oceania (Australia, New Zealand), South America (Brazil, Argentina, Colombia, Chile, Venezuela, Peru, Puerto Rico, Ecuador), the rest of the world (Kazakhstan and others).

The main operators of the interferometer market include Renishaw Plc., OptoTech Optikmaschinen GmbH, BRUKER, KLA, NanoFocus AG, Optodyne, Palomar Technologies, Inc., 4D Technology, XONOX Technology GmbH, Trioptics, Inc., API, CTRI, Carl-Zeiss, Status Pro, Olympus, Fujifilm, Aerotech Inc, Keysight, KYLIA, Zygo Corporation, Tosei Engineering Corp., Haag-Streit Holding AG, and others.

The largest market of interferometry belongs to manufacturers from North America. The cost of production of interferometers by the enterprises of this region in 2019–2021 was about 38.2% of their total cost.

The industries that account for the largest share in the production of interferometers in the world include the following ones: automotive, consumer electronics, aerospace, semiconductor, ophthalmic, etc. [82].

The main drivers that stimulate the development of the consumer value of interferometers include the improvement in the accuracy of measurements, the development of high technology based on optics, the tendency to simplify the process of setting up devices, a focus on solving specific problems, etc., whereas a limiting factor includes the growth of the industry average value of interferometers.

The development of digital technologies on a global scale during 2021–2028 will stimulate the appearance of new opportunities in the field of interferometry, which will lead to significant market expansion. In particular, according to the forecast data, from 2020 to 2025, the market of laser interferometers will grow from USD 237 to 334 million dollars; its CAGR indicator will account for 7.1% [83].

In 2021, 30.2% of the world market was occupied by the interferometers of linear optics, which include the author's R&D product [82].

The key factor in expanding the market of interferometers is considered to be the growing demand for 3D-metrological services, paying great attention to quality control in the industry, the development of R&D based on strengthening the innovation activity of technologically leading countries, etc. In the coming years, a special demand for interferometers will be observed in the automotive, aerospace, and defense industries.

Based on the results of the study [84], the change in profitability from the sale of interferometers in the world by their types, as well as the forecast data for such a change (2016–2028), show its significant growth in all types of this product [84]. Overall, the profitability growth rate from the sale of interferometers is expected to be over 20% for the following product types: Laser Fizeau, Mach—Zehnder, Michelson, Fabry – Pérot. For Sagnac and Common path Interferometers, this level will be over 30%, and for Fiber and Twyman Green Laser types—over 40%.

The change in the profitability of interferometers by the industry of their use during 2015–2027 indicates that during the analyzed period, there is a significant increase in this indicator for all types of industry. However, the highest growth rates are characteristic of Biology and Medicine (over 20% in 2027), as well as Engineering and Applied Science (over 15% in 2027), slightly lower in Physics and Astronomy, and others. This situation is explained by the rapid development of science-intensive and high-tech segments of the economy, marked by the global influence of the fourth Industrial Revolution as a whole.

The distribution of interferometers by regional segments during 2016–2028 shows that the largest share of production and sales of this product during the analyzed period is observed in the North American region: almost all years, this region owns half of the global market for interferometers.

The functional segments of interferometers and their coverage by the current market operators (2021) are shown in Table 2.

Table 2. Functional segments of interferometers and their coverage by the existing market operators, 2021 [1].

Main Market Operators, Countries	Aerospace	Aviation	Defense	Biotechnology, Medicine,health care	R & D	Automotive	Telecommunication, Smart-Technologies	Automotive	Industrial Decisions (Processing, etc.)	Heavy Industry	Power Engineering	Metrology
Renishaw Plc. (Great Britain, England)	+		+	+	+	+	+	+	+	+		+
OptoTech Optikmaschinen GmbH (Germany)				+		+					+	
BRUKER (USA)				+		+		+		+		
KLA (USA)						+		+			+	
NanoFocus AG (Germany)					+	+		+			+	
Optodyne (Italy)					+	+		+			+	
Palomar Technologies Inc. (USA)					+	+						
4D Technology (USA)						+		+			+	
XONOX Technology GmbH (Germany)					+	+					+	
Trioptics Inc. (USA)						+		+			+	
Carl-Zeiss (Germany)	+	+		+	+	+	+	+	+	+	+	+
Status Pro (Germany)					+		+				+	
Olympus (Japan)				+		+		+				
Fujifilm (Japan)				+								
Aerotech Inc. (USA)	+	+	+	+	+	+	+	+	+	+		+
Keysight (USA)	+	+		+	+	+	+	+	+	+	+	+
KYLIA (France)					+	+						
Zygo Corporation (USA)	+	+	+	+	+	+	+	+	+	+	+	+
Tosei Engineering Corp. (Japan)						+	+	+			+	
Haag-Streit Holding AG (Switzerland)				+	+							

[1] Source: made up by the authors based on the results of their research.

The market of interferometry devices is characterized by a growing demand for laser interferometers and a tendency to replace other types of interferometers with them, due to the expanded list of opportunities provided by laser interferometers.

Most interferometers on the world market (Table 2) are characterized by significantly lower measurement accuracy indicators, in contrast to the author's R&D product, which gives the accuracy of up to five decimal places.

3.2.2. Analysis of the Interferometer Market in Ukraine

The analysis of the interferometer market in Ukraine gives grounds to claim on:

- the lack of a developed market of the interferometer in Ukraine;
- dissatisfaction with the need for interferometers for R&D by domestic research institutions;
- in Ukraine, the production of interferometers of different types is represented by the following companies: "UKRGEO-PROJECT" Ltd. (Kyiv, Ukranie), "SPECTRO LAB" Ltd. (Kyiv, Ukranie), National Academy of Sciences, National Scientific Center "Institute of Metrology", Ukrainian Institute of Scientific and Technical Expertise and Information, "Ukrainian Optical Systems" Ltd. (Kyiv, Ukraine), profile universities of Ukraine, etc.;
- the representation of products of foreign manufacturers of interferometers mostly extends to the EU countries of the Near Abroad and developing markets; as in Ukraine the products of these companies are still presented in fragments, it is significantly more expensive than the author's device based on the interferometric determination of the refractive index of crystalline materials in the optical range.

The study of the interferometer market in the world and Ukraine, as well as prospects for the development of interferometry as a scientific and applied field in the context of the spread of the fourth Industrial Revolution, indicates the relevance of the author's R&D product. The special need for this technology is evidenced by research institutions of Ukraine, which are engaged in developments in the defense and telecommunications spheres of domestic science. Given the war in eastern Ukraine, which requires the development of new means and devices for defense, as well as the development of the telecommunications market due to the rapid pace of the digitalization and intellectualization of technology, the proposed R&D product is primarily appropriate for R&D and production in these areas. The market needs comprehensive decisions in the field of interferometry. The application of the author's technology of the interferometric determination of the refractive index of crystalline materials in the optical range will help to obtain a higher level of measurement accuracy, software configuration efficiency, the precision of device manufacturing elements, etc. These and other characteristics are the keys to a positive economic effect for both businesses and end-users.

To substantiate the possibility of commercialization of the author's product, the profiles of industries (their attractiveness is assessed), promising for this purpose, should be formed. The studies show that such industries are the telecommunications and defense ones. The subjects of these industries include research institutions, production and research enterprises that perform profile measurements or manufacture devices based on interferometry.

Based on the generalization of analytical data on the development of interferometry technologies, the nature of strategic management areas for such technologies in Ukraine (telecommunications and defense market) is assessed; the changes in market trends for the author's R&D product are analyzed. From the results of the analysis, it is seen that both of these strategic areas of management are characterized by a tendency of the domination of favorable factors influencing profitability.

Thus, the projected market position of the device with the technology of interferometric determination of the refractive index of crystalline materials in the optical range indicates potential prospects for the commercialization of this R&D product and its stable competitiveness over time.

3.3. Cost Estimate of the R&D Product

3.3.1. Evaluation of the R&D Product by Cost Approach Methods

To estimate a R&D product for commercialization effectively, evaluators should consider the number of costs incurred during its development as a basis for further calculations, below which it is not recommended to set a price (except the cases stipulated by special marketing strategies of the market launch of the respective R&D product). The basis for pricing, according to the cost approach, is the basic costs per unit of output (development) to which a compensatory allowance is added intended to reimburse unaccounted costs and profits. A lower limit of the price is determined in this way. To do this, a traditional approach to the formation of the cost structure of products is used, which is adapted to the specific evaluation situation. At the same time, the final price for the R&D product is mostly higher than the estimated one.

The main normative document that defines the general principles and procedure for forming the cost of production is P(S)A 16, approved by the Decree of the Ministry of Finance of Ukraine № 318 [85]. The direct procedure and features are given in branch methodical recommendations. The preparation of the actual (reporting) calculation and the calculation of the actual (reporting) cost are mandatory for manufacturing enterprises. The planned and normative calculation is made at the discretion of the enterprise and is used mainly for management accounting.

To set the price of the device of the interferometric determination of the refractive index of crystalline materials in the optical range, a list of direct costs (raw materials, materials, purchased products, semi-finished products, production services of third parties, etc.) incurred by the authors during the development of the R&D product, which is a basis of this device, is formed. Based on the data on the works carried out by the developers for the preparation of the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range, as well as the information obtained in the process of research on the manufacture of the device based on this method, a price for it is set. The functional segment for such a device is the laboratories of enterprises, research institutions, etc. in the subject area. The formed price structure for the device of the interferometric determination of the refractive index of crystalline materials in the optical range is given in Table 3.

Let the authors determine the level of the break-even point (*BEP*) of the implementation of the analyzed device by the expression:

$$BEP = TFC/(P - AVC) = TFC/C, \quad (1)$$

where *BEP* is a break-even point level, units; *TFC* is a total fixed cost, thousand UAH; *AVC* is an average variable cost (per unit of output), thousand UAH; *P* is a unit sale price, thousand UAH; *C* is the profit per unit of output excluding fixed costs, thousand UAH.

Therefore:

$$BEP = 27.58/(38.8 - 27.58) = 2.46 \approx 3 \text{ units.} \quad (2)$$

The level of break-even sales is 3 units of devices. According to the calculations, the price of the analyzed device of the interferometric determination of the refractive index of crystalline materials in the optical range will be 510.94 thousand UAH, in which the cost accounts for 474.14 thousand UAH.

The cost approach is generally considered to be the fairest among the others, but it does not include the conditions of demand formation and the economic value of the R&D product, because the price is determined based on actual costs, without including alternative ones. The costly methodological approach uses average rather than marginal costs as a basis for pricing, based only on available data, without the need for market research or consumer surveys.

Table 3. Price structure for the device of the interferometric determination of the refractive index of crystalline materials in the optical range [1].

№	Indicators, Measurement Units	Values of Indicators
1	Direct costs, thousand UAH	444.56
1.1	raw materials and materials, thousand UAH	192.46
1.2	returnable waste (subtracted), thousand UAH	-
1.3	purchased products, semi-finished products and production services of third parties, thousand UAH	60.8
1.4	fuel and energy for technological purposes, thousand UAH	11.3
1.5	wages of production workers, thousand UAH	132.1
1.6	deductions for social events, thousand UAH	47.9
1.7	losses from spoilage, thousand UAH	-
	Direct costs, thousand UAH	444.56
2	Indirect costs, thousand UAH	27.58
2.1	overhead costs, thousand UAH	18.1
2.2	general expenses, thousand UAH	6.3
2.3	other production costs, thousand UAH	3.18
2.4	commercial expenses, thousand UAH	-
3	Profit, thousand UAH	38.8
4	Price, thousand UAH	510.94

[1] Source: calculated by the authors based on the information obtained from the developers of the product. In addition, the use of the LabView package software is planned for the operation of the device (the cost of the license is 10.8 thousand/year UAH).

3.3.2. Evaluation of the R&D Product by the Methods of a Comparative Approach

The evaluation of the R&D product is a task of the dual-level of complexity, which is to find the best price at which, on the one hand, the consumer (investor, manufacturer) is willing to buy it, and, on the other hand, the seller (developer) is willing to sell it (maximum possible). However, due to the innovativeness of the R&D product, in many cases, there are problems in finding the information necessary for its adequate evaluation and the proper application of processing methods. Among the most popular approaches to the evaluation of the R&D product, a comparative one is considered as such. The evaluated R&D product is compared with similar developments presented on the market or by individual characteristics of its competitive analogues.

According to the Methodology of Valuation of Intellectual Property Rights (Decree of the State Property Fund, №740) [86], the price of an innovative product is determined by adjusting the prices for market analogues of products. For example, these may be prices resulting from the conclusion of agreement, etc. Accordingly, the R&D assessment process will depend on the chosen base for comparison.

Pricing by a comparative evaluation approach for the device of the interferometric determination of the refractive index of crystalline materials in the optical range and the justification of the possibility of its further commercialization should be based on the market analysis of similar interferometers in the world and Ukraine. According to the results of such an analysis, given in Section 3.2, several key features that will determine the competitive position of the author's device on the market are distinguished, namely:

- universality of the interferometer application;
- software that allows getting results digitally and visualizing data, performing their calculations directly in the program;
- compactness and precision of the elements of the device manufacturing;
- possibility to measure plane-parallel and non-plane-parallel (wedge-shaped) samples;
- high-precision measurements of the refractive index at a given wavelength in the visible range;
- accuracy of the refractive index measurement (up to five decimal places);
- measurement of the refractive indices of isotropic and anisotropic materials;
- taking into account the refractive index of the medium in which the test sample remains;
- possibility of rapid analysis of the refractive indices of optical materials;

- low price for the device, etc.

Based on the conducted market research, some enterprises from the set of existing ones on the market that offer competitive products for the device are identified (see Table 2). To perform calculations, the authors selected from the analyzed enterprises those that constitute the highest level of compliance of analogues in terms of competitive parameters of the author's R&D product and classified them into two groups by regional location, namely enterprises of the North American region and enterprises in Europe and other regions of the world.

To determine the competitive price of the device for the interferometric determination of the refractive index of crystalline materials in the optical range based on a comparative approach further, the authors conducted an expert survey, which allowed for assessing the weight of this or that feature from the list of the above, according to competitive analogues. For this purpose, the gradation of qualitative estimates of the signs of impact on the formation of the R&D product price is formed (Table 4).

Table 4. Gradation of the qualitative estimates of the signs of impact on setting the R&D product price [1].

Gradation of the Estimates of Impact Signs	Value of the Sign (Range 1 ... 9.9)
The weakest impact	1.0–1.9
Insubstantial influence	2.0–3.9
Temperate impact	4.0–5.9
Significant impact	6.0–7.9
Strong influence	8.0–9.9

[1] Source: developed by the authors.

The gradation given in Table 4 made it possible to substantiate the differences between the evaluation products. A total of 16 specialists in the subject area took part in the expert evaluation. Their opinions were checked for consistency with a concordance ratio of 95.47%, which indicates a high level of consistency of expert positions on the evaluated signs of competitiveness. The obtained estimates are reduced by the method of the arithmetic value to the average one in the group and are weighed using the appropriately weighted coefficients.

To evaluate by a comparative approach, the number of selected analogue objects should be larger by one by the number of adjustment factors, i.e., $n = k + 1$, where n is the number of analogue objects; k is the number of adjustment factors. This is taken into account when generating the output data in Tables 5 and 6, which show the results of the evaluation and market prices of the competitive analogues by region.

To compare the competitive analogues based on the survey results, the expression [87] is used:

$$P_{int} = P_a + \sum_{j=1}^{m} \Delta P_{aj}, \tag{3}$$

where: P_{int} is the price of a product, units; P_a is the selling price of a similar product (device, technology), units; k is the number of signs to compare; ΔP_{aj} is the correction in the price of the sale of a similar technology, by j-sign of comparison; the author's R&D product is compared with each of the selected analogues. The comparison is formalized using a system of linear equations, which for the convenience of further solutions are advised to write in a matrix form:

$$\Delta X P' = P \tag{4}$$

$$P' = \left\{ \begin{array}{c} P_{int} \\ \dots \\ \Delta P_n \end{array} \right\}, \tag{5}$$

$$P = \left\{ \begin{array}{c} P_1 \\ P_2 \\ \cdots \\ P_m \end{array} \right\} \quad (6)$$

$$\Delta X^{-1} = \left\{ \begin{array}{cccccccc} 1.3187 & 0.3140 & -0.1467 & -0.8731 & 0.9123 & -1.5578 & -2.5834 & 1.0248 \\ 0.3176 & 0.7980 & -0.3459 & -0.8765 & 0.2846 & -0.2951 & 0.1381 & -0.1630 \\ -0.5937 & -0.5998 & 0.0518 & 0.6832 & -0.7332 & 0.0074 & -0.2856 & 0.8519 \\ -0.9628 & -0.4456 & -0.1891 & 0.6399 & 1.0340 & 0.8726 & 0.6193 & -0.0729 \\ 0.7729 & -0.2346 & 0.9970 & -0.2633 & 0.1988 & -0.3728 & -0.9826 & 0.5283 \\ 0.2453 & -0.2995 & -0.3434 & -0.6592 & 0.1519 & 2.2832 & 0.2777 & 0.3820 \\ -0.1392 & 0.8839 & -0.0381 & 0.5674 & -0.9274 & -0.7280 & -0.1582 & 0.2817 \\ -0.8635 & 0.8720 & 0.5628 & -0.5559 & -0.0439 & -0.0952 & 0.2382 & -0.3571 \end{array} \right\} \quad (7)$$

Table 5. Results of the evaluation and market prices for competitive analogues of the device for the interferometric determination of the refractive index of crystalline materials in the optical range (North American region) [1].

Signs	BRUKER	KLA	Palomar Technologies Inc.	4D Technology	Trioptics Inc.	Aerotech Inc.	Keysight	Zygo Corporation	Author's Device
Software that allows getting results digitally and visualizing data	8.1	7.3	8.0	7.0	7.1	9.1	9.0	8.9	8.1
Compactness and precision of the elements of the device production	7.9	8.1	7.9	8.4	8.1	6.9	7.1	6.8	8.1
Possibilities of measuring plane-parallel and non-plane-parallel (wedge-shaped) samples	6.1	5.3	6.2	6.7	7.1	9.1	8.4	7.3	9.1
Carrying out high-precision measurements of the refractive index at a given wavelength in the visible range; accuracy of the refractive index measurement (up to five decimal places)	7.1	6.8	6.5	6.3	7.5	8.7	8.6	8.3	9.3
Measurement of the refractive indices of isotropic and anisotropic materials	4.2	3.8	3.1	5.2	4.9	5.1	6.7	7.1	6.8
Taking into account the refractive index of the medium in which the test sample remains	5.3	4.9	6.1	5.9	7.3	8.1	7.0	8.3	8.1
Possibility of carrying out the express-analysis of the refraction indices of optical materials	6.8	6.9	6.4	4.3	7.5	6.5	6.5	7.9	9.2
Price, thousand UAH	252.18	222.21	213.57	282.69	251.37	411.48	335.61	183.06	X

[1] Note: product prices—competitive analogues are taken from open sources.

Table 6. Results of the evaluation and market prices for competitive analogues of the device for the interferometric determination of the refractive index of crystalline materials in the optical range (enterprises in Europe and other regions of the world) [1].

Signs	BRUKER	KLA	Palomar Technologies Inc.	4D Technology	Trioptics Inc.	Aerotech Inc.	Keysight	Zygo Corporation	Author's Device
Software that allows getting results digitally and visualizing data	8.2	7.4	7.1	7.1	8.9	7.3	6.7	5.9	8.3
Compactness and precision of the elements of the device production	7.9	8.2	7.9	7.9	9.3	7.4	9.1	6.8	8.9
Possibilities of measuring plane-parallel and non-plane-parallel (wedge-shaped) samples	8.9	7.2	6.9	7.0	8.9	8.3	6.0	5.9	9.1
Carrying out high-precision measurements of the refractive index at a given wavelength in the visible range; accuracy of the refractive index measurement (up to five decimal places)	6.1	6.8	6.5	6.3	9.1	8.9	7.1	6.3	9.1
Measurement of the refractive indices of isotropic and anisotropic materials	4.3	4.8	3.3	4.2	5.9	5.0	3.2	3.4	6.5
Taking into account the refractive index of the medium in which the test sample remains	6.3	4.9	5.1	5.9	8.3	7.2	5.4	5.3	8.2
Possibility of carrying out the express-analysis of the refraction indices of optical materials	5.3	5.8	4.9	3.8	8.1	8.2	7.0	6.1	9.1
Price, thousand UAH	281.34	96.12	247.86	336.15	567.0	411.48	146.61	366.66	X

[1] Note: product prices—competitive analogues are taken from open sources.

Based on the obtained results, we can calculate the elements of the matrix P_{int} by expressions (4–6):

$$P' = \begin{Bmatrix} P_{int} \\ \Delta P_1 \\ \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \Delta P_5 \\ \Delta P_6 \\ \Delta P_7 \end{Bmatrix} = \begin{Bmatrix} 537.24 \\ -3.7629 \\ 11.6298 \\ -2.8201 \\ 1.8091 \\ -14.1239 \\ 5.3816 \\ 5.5428 \end{Bmatrix} \quad (8)$$

Parameter P_{int} is an average market price of the evaluated object—a device for the interferometric determination of the refractive index of crystalline materials in the optical range. The calculation results show that taking into account the main selected features of competitiveness, their aggregation based on matrix formalization, the author's device in the market of the North American region, it is advisable to set a price at 537.24 thousand UAH. The obtained price is a value that takes into account the specifics of the market in the analyzed period. Other elements of the matrix (8) reflect the adjustment of the device price, under the stipulated economic content of the sign of impact (Table 7).

Table 7. Interpretation of the results of the evaluation of the influence of competitive characteristics on the price formation for the device of the interferometric determination of the refractive index of crystalline materials in the optical range [1].

Signs	Economic Interpretation of the Obtained Results by Signs, Measurement Units
ΔP_1	The price adjustment value depending on the use of software that allows getting results in digital form and visualizing data, thousand UAH.
ΔP_2	The price adjustment value depending on the level of compactness and precision of the elements of the device, thousand UAH.
ΔP_3	The price adjustment value depending on the possibility to measure plane-parallel and non-plane-parallel (wedge-shaped) samples, thousand UAH.
ΔP_4	The price adjustment value depending on the possibility of high-precision measurements of the refractive index at a given wavelength in the visible range, the accuracy of the refractive index measurement (up to five decimal places), thousand UAH.
ΔP_5	The price adjustment value depending on the measurement of the refractive indices of isotropic and anisotropic materials, thousand UAH.
ΔP_6	The price adjustment value depending on the refractive index of the medium in which the prototype remains, thousand UAH.
ΔP_7	The price adjustment value depending on the possibility of express-analysis of the refractive indices of optical materials, thousand UAH.

[1] Source: substantiated by the authors.

Therefore, given the assessed market situation:

- the level of a software application rate for the device is declining; due to this feature, the author's product price reduced by 3.76 thousand UAH;
- the level of compactness and precision of the device elements tends to increase; due to this feature, the author's product price increased by 11.63 thousand UAH;
- the indicator of measurements of plane-parallel and non-plane-parallel (wedge-shaped) samples is characterized by a decrease; due to this feature, the author's product price reduced by 2.82 thousand UAH;
- the level of the indicator of high-precision measurements of the refractive index is characterized by an increase; due to this feature, the author's product price increased by 1.81 thousand UAH;
- the level of the refractive index measurement of isotropic and anisotropic materials is declining; due to this feature, the author's product price reduced by 14.12 thousand UAH;
- the level of the refractive index of the medium in which the test sample remains, upward trend; due to this feature, the author's product price increased by 5.38 thousand UAH;
- the level of the rate of express-analysis of the refractive indices of optical materials tends to increase; due to this feature, the author's product price increased by 5.54 thousand UAH.

Similar price calculations were performed for the device of the interferometric determination of the refractive index of crystalline materials in the optical range for the market of Europe and other regions. Based on Table 6 and the results of calculations of the inverse to ΔX matrix ΔX^{-1} using the software package MATLAB, the following results were obtained:

$$\Delta X^{-1} = \left\{ \begin{array}{cccccccc} 1.8723 & 0.7293 & -0.6250 & -0.7382 & 0.8219 & -1.5783 & -1.4619 & 2.6293 \\ 0.1843 & 0.6820 & -0.5845 & -0.8236 & 0.1638 & -0.8853 & 0.1285 & -0.3742 \\ -0.6564 & -0.1630 & 0.5628 & 0.1428 & -0.5578 & 0.7734 & -0.3826 & 0.8566 \\ -0.7746 & -0.2982 & -0.1719 & 0.2873 & 0.9826 & 0.6382 & 0.4629 & -0.0034 \\ 0.5786 & -0.5629 & 0.2783 & -0.6564 & 0.7354 & -0.7293 & -0.2755 & 0.6283 \\ 0.4580 & -0.5492 & -0.5453 & -0.7239 & 0.6651 & 1.1213 & 0.8926 & 0.2297 \\ -0.3692 & 0.7266 & -0.9826 & 0.2046 & -0.9667 & -0.3382 & -0.1512 & 0.2045 \\ -0.0762 & 0.5549 & 0.1813 & -0.0551 & -0.8364 & -0.0026 & 0.2528 & -0.3829 \end{array} \right\} \quad (9)$$

Based on the above results, the elements of matrix P_{int} are calculated by expressions (4–6):

$$P' = \begin{Bmatrix} P_{int} \\ \Delta P_1 \\ \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \Delta P_5 \\ \Delta P_6 \\ \Delta P_7 \end{Bmatrix} = \begin{Bmatrix} 541.38 \\ -4.6382 \\ 11.1530 \\ -3.4516 \\ 2.3982 \\ -7.1842 \\ 6.3435 \\ 1.1763 \end{Bmatrix} \quad (10)$$

The obtained results of the calculation, which contain the features of competitiveness of the author's device in the market of Europe and other regions of the world, indicate the recommended price for this device at the amount of 541.38 thousand UAH. The other elements of the matrix (8) reflect the adjustment of the price of the device, under the stipulated economic content of the sign of impact (Table 7).

Thus, given the assessed market environment in the subject area of Europe and other regions of the world:

- the level of a software application rate for the device is declining; due to this feature, the author's product price reduced by 4.64 thousand UAH;
- the level of the rate of compactness and precision of the elements of the device production tends to increase; due to this feature, the author's product price increased by 11.15 thousand UAH;
- the indicator of the measurements of plane-parallel and non-plane-parallel (wedge-shaped) samples is characterized by a decrease; due to this feature, the author's product price reduced by 3.45 thousand UAH;
- the level of the indicator of high-precision measurements of the refractive index is characterized by an increase; due to this feature, the author's product price increased by 2.40 thousand UAH;
- the level of the refractive index of isotropic and anisotropic materials is declining; due to this feature, the author's product price reduced by 7.18 thousand UAH;
- the level of the refractive index of the medium in which the test sample remains, upward trend; due to this feature, the author's product price increased by 6.34 thousand UAH;
- the level of the rate of express-analysis of the refractive indices of optical materials tends to increase; due to this feature, the author's product price increased by 1.18 thousand UAH.

There are several supplements' additions and remarks to the given interpretation; in particular, the value of the market price and corrective indicators are determined by the input data of the formed evaluation system; therefore, the obtained values are approximate, aimed at assisting appraisers in making decisions on a price adjustment for a R&D product. The method does not allow verifying the fulfillment of all conditions necessary for the price of an author's product to be considered on the market and does not fully reflect the technical and economic characteristics of an author's product—competitive analogues; it requires the collection of a significant number of data points for evaluation.

3.3.3. Evaluation of the R&D Product by Methods of the Income Approach

Based on the study of the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range and using NASA methodology on the technological readiness of developments of NASA [88], the analyzed author's product is at the eighth level of technological readiness.

Let the authors note that in the case of the analyzed R&D product, the inexpediency to use the methods of income approach for pricing is obvious because it is important to predict the number of devices offered for commercialization accurately. Such forecasting should be based on the identification of potential customers (consumers) based on their survey and an assessment of their readiness to purchase this R&D product at a specific price. It is necessary to determine the degree of the desire of buyers to pay a certain price for the proposed added value (see the competitive characteristics given in Section 3) of the analyzed device. This requires additional research on the sensitivity of consumers to the price of the device. Consumer sensitivity indicators can be decisive during the transfer and commercialization of the R&D product.

Using the research results (markets considered for the launch of the author's R&D product, the competitive features of development, economic development trends, etc.), several economic indicators of the project of commercialization of the author's device are calculated under the income methodological approach which should be taken as a basis in case of investment interest. The method of multipliers is chosen for calculations, and the level at which there is a break-even point of realization of the analyzed devices is taken into account—3 units.

The main indicators of the project of the commercialization of the device of the interferometric determination of the refractive index of crystalline materials in the optical range are given in Table 8.

Table 8 shows the economic indicators that will characterize the implementation of the author's product of the interferometric determination of the refractive index of crystalline materials in the optical range for three years after the year of a project launch. The output data are formed based on previous studies of the market environment of this product and the peculiarities of its development.

The calculation results show that the price of the estimated R&D product will change over time, depending on the forecast elasticity of demand and rising prices for interferometers in the market as a whole. The number of expenses in the cost of the device will decrease over time, as the number of indirect costs per unit of output will decrease. The given discount rate reflects the level of risk of the market launch of this device. The value of the project "pre-money" will be 4168.60 thousand UAH, "post-money"—5156.56 thousand UAH.

Having performed the evaluation for a R&D product—a device of the interferometric determination of the refractive index of crystalline materials in the optical range, we obtained a range of price values for this product: from 510.94 UAH thousands at the break-even point of three devices (a price obtained according to the cost approach) to 537.24 UAH thousands for the market of the North American region and 541.38 UAH thousands for the European market and other regions of the world (according to the comparative approach). Consequently, under the indicated terms, a price for this product cannot be lower than 510.94 UAH thousands. At the same time, it is not expedient to set a price exceeding 510.94 UAH thousands or 537.24 UAH thousands (depending on the chosen market) because it will not ensure competitive positions for this product. Prices calculated in such a way take into account the specificity of a market within a certain period of evaluation. Correspondingly, they will satisfy all parties of a transfer arrangement and give room for maneuvers concerning commercial decisions. This assertion confirms the proof of ***Hypothesis 1***.

Table 8. Economic indicators of the project of the commercialization of the device of the interferometric determination of the refractive index of crystalline materials in the optical range, determined by the income methodological approach [1].

№	Indicators, Measurement Units	Launch	1st Year	2nd Year	3rd Year
1	Number of products sold, units	-	3	3	3
2	Price, units	-	510.94	515.81	517.82
3	Costs, units	-	474.14	423.75	408.64
4	Income from the sales, thousand UAH	-	1532.82	1547.43	1553.46
5	LTM income	x	x	x	4633.71
6	Net cash flow from operating activities, thousand UAH	-	110.4	278.18	327.541
7	Discount rate, %	34.3	34.3	34.3	34.3
8	Discount coefficient	1.0	0.74	0.55	0.41
9	Discounted cash flow, thousand UAH	-	81.69	152.99	134.29
10	Value multiplier				2
11	Post-forecast (terminal) cost, thousand UAH	x	x	x	9267.4
12	Discounted terminal value, thousand UAH	3799.634	-	-	-
13	Project cost (pre-money), thousand UAH	4168.60	-	-	-
14	Invested capital, thousand UAH	987.96			
15	Project cost (post-money)	5156.56			
16	Investor's share%	3.7	3.7	3.7	3.7
17	Value of the investor's share, thousand UAH	190.79			
18	Investor's cash flow, thousand UAH	−190.79	4.084	10.29	12.12
19	Investor's profit when leaving the business, thousand UAH	-	-	-	481.90
20	Investor's final cash flow, thousand UAH	−190.79	4.084	-	494.02

[1] Source: calculated by the authors.

3.4. Concept of Providing Competitive Benefits of the R&D Product

The determined prices for the R&D product—the interferometric determination of the refractive index of crystalline materials in the optical range—do not entirely meet all the terms required for effective commercialization of this product. To provide effective commercialization of the product, we need to do additional research regarding sensitivity and elasticity of demand alongside the readiness of customers to purchase this product at the indicated price. Consequently, ***Hypothesis 2*** does not come true completely.

In addition, the analysis of the competitiveness potential and market environment of the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range shows that for its successful commercialization, it is necessary to apply the market launch strategy using existing and forming new competitive benefits.

The key provisions of the concept of providing competitive benefits for the period of project implementation for the commercialization of the device of the interferometric determination of the refractive index of crystalline materials in the optical range are given in Table 9.

Table 9. Concept of providing competitive benefits for the period of project implementation for the commercialization of the interferometric determination of the refractive index of crystalline materials in the optical range [1].

2022–2024	2024–2026
General strategy	
Focus on low costs	Leadership in compliance with affordable prices and high quality of the device
General policy	
Operating cost saving	
Strategic goal—reducing the cost of the device, finding new customers, improving the quality of their service	
Economic mechanism for achieving the goal	
Saving of direct costs, improving device maintenance, reducing overhead costs	Saving of material costs, maintaining the high quality of the device, increasing the level of customer service

[1] Source: made up by the authors.

The strategic highway of the market distribution of devices of the interferometric determination of the refractive index of crystalline materials in the optical range for the period up to 2026 should combine the following strategies: focus on low costs—2022–2024; leadership in compliance with affordable prices—2024–2026.

A capacity increase through the services of the maintenance of the author's interferometers will allow working at the highest technological level and provide a basis for the transition to the strategy of differentiation, which aims to innovate the product. The type of relationship with consumers is "personal support".

4. Analysis

The application of the proposed holistic approach to R&D products' evaluation for commercialization, which is based on a combination of the methods of cost, comparative, and income methodological approaches, shows the possibility of the comprehensive evaluation of worthy and value indicators of the R&D product.

The cost approach applied to the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range allowed calculating the price that will compensate the developer of the R&D product future benefits from possible ownership of it. This price is 510.94 thousand UAH, at the level of break-even sales in the number of three devices. This price of the R&D product is characterized by a lower level of risk than the prices determined by the other methodological approaches, as it takes into account the actual costs of the developer—474.14 thousand UAH. At the same time, the application of this approach does not take into account the demand and economic value of the R&D product, as its price is determined according to actual costs, based only on available data, and not alternative ones. The obtained price is a basis for further calculations, below which it is not recommended to set a price for this R&D product.

To apply the comparative methodological approach to evaluate the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range effectively, the output technical and economic parameters of the R&D product are analyzed, and a thorough marketing study was conducted to determine the location of these parameters in a competitive environment. The comparative approach made it possible to set a market price by analyzing similar R&D products, taking into account the probabilistic nature of such a price—537.24 thousand UAH (for the market of the North American region) and 541.38 thousand UAH (for the market of Europe and other regions of the world). The obtained prices take into account the specifics of the market in the analyzed period. In addition, this approach makes it possible to identify and quantify the factors influencing certain competitive characteristics, which should be taken into account when evaluating the device. This allows the developer to adjust the priority or the possibility of replacing certain characteristics of the device that determine its competitiveness. However, a comparative approach does not allow checking the fulfillment of all conditions regarding the real competitiveness of the R&D product price. It does not reflect the technical and economic characteristics of products—competitive analogues to a sufficient extent. This requires a significantly larger number of data points to be used in the evaluation. The prices obtained by the comparative method are useful in the case of making decisions to adjust prices for the R&D product.

The practical complexity of applying a comparative methodological approach to evaluating the R&D product on the Ukrainian market is explained by the lack of a developed market of interferometers. The representation of products of foreign manufacturers is fragmentary; they are significantly more expensive than the author's device. Foreign devices available on the Ukrainian market are not fully comparable in characteristics with the author's product.

5. Discussion: Holistic Approach in R&D Evaluation and Open Innovation

The application of the comparative methodological approach made it possible to identify priority areas for a market launch of the product of the interferometric determination of the refractive index of crystalline materials in the optical range. These are telecommunications and defense industries; their entities include research institutions, production and research enterprises that conduct profile measurements or manufacture devices based on interferometry.

The application of the income methodological approach is based on the break-even level of sales of the evaluated R&D product in the number of three devices. However, this quantity must be confirmed based on the survey and assessment of the readiness of potential customers to purchase this R&D product at a specific price. This leads to additional research on the sensitivity of consumers to the device, which is a determining factor in the effectiveness of the income approach implementation.

Based on the research, several economic indicators of the project of the commercialization of the author's device are calculated, which can be obtained under the level of actual expenses determined by the cost method and quantitatively justified factors of a price change determined based on the comparative method. The value of the project "pre-money" will be 4168.60 thousand UAH, "post-money"—5156.56 thousand UAH.

According to the results of the evaluation of the product of the interferometric determination of the refractive index of crystalline materials in the optical range, it is obvious that the application of a holistic approach to R&D products' evaluation for commercialization gives a comprehensive view of the R&D product price, its market role, and development prospects. The proposed holistic approach makes it possible to set a price that will satisfy all the parties to a transfer agreement with a higher level of accuracy and will meet the requirements of the market. Therefore, ***Hypothesis 1*** is true.

Hypothesis 2 is not fully true as the received prices do not sufficiently satisfy the conditions of the effective commercialization and market launch of the R&D product, because they are not confirmed by the willingness of customers to purchase this R&D product at a specific price. This requires studying the sensitivity of consumers to the device price.

The proof the hypotheses indicated at the beginning of this article enabled the development of the holistic approach to evaluating the R&D product, as well as the formulation of a set of important conclusions on its application. Particularly, ***Hypothesis 1*** allowed for making the following assertions:

- higher levels of precision and accuracy are inherent to prices calculated according to the holistic approach since these prices are affirmed by the cross-sectional examination of R&D product impact factors. In turn, this will enable the prediction of competitive positions of the product before its launch and take into consideration risks of scaling up, etc.;

- optimal prices are conducive to the maneuverability of managerial decisions in relation to further sales of the product by a customer (an investor, etc.) at the expense of opportunity to show a range of values;
- a complex analysis of R&D product's prospects in a market is provided;
- use of the holistic approach for evaluating R&D products allows experts to prognosticate the emergence of complicated market effects and phenomena, which may happen in relation to the product after its commercialization (the diffusion, convergence, spillover effects, multiplying the product value, etc.);
- experts of a substantive area are enabled to manage a set of analytical data and conclusions in the field of interferometers and interferometry.

The elaboration of ***Hypothesis 2*** enabled proof that:

- it is impossible to take into account all requirements and terms of planned commercialization and a market launch of the product in the phase of product evaluation, but it is possible to increase the level of precision for such prognostication significantly;
- applying the holistic approach to the economic evaluation of R&D products for their commercialization frequently requires additional rigorous research, which is inevitable if you want to obtain substantiated conclusions on pricing.

The conducted analysis partially allows us to agree with the scientists' ideas [49–55,77–80] concerning opportunities opened by the holistic approach. However, in the process of its practical application, experts may deal with bottlenecks, which may considerably distort results of analyzing since there is no mention of them in the literature. Particularly, the proof of the hypotheses established in this article showed that bottlenecks of the suggested holistic approach to the R&D products evaluation encompass:

- a need for studying consumers' sensitivity to the device's price and price elasticity of demand;
- a possibility for the economic evaluation of this product only under the determined terms (for a certain consumer, opportunities of a manufacturer, conditions for the development of a market environment, etc.); thus, results of such an analysis may be irrelevant even during a short period of time;
- the complexity of determining the basis for product evaluation (particularly, with regard to components of the comparative methodical approach);
- if research of a R&D product is conducted during the work on government-funded projects, e.g., at university laboratories, the substantiation of costs becomes harder: since the costs are incurred during a long-term period, in the process of calculating their present value, their amount may turn out to be excessively large. This phenomenon will lead to the inadequate increase in a product's price.

The suggested holistic approach is one of the aspects of developing the methodology for R&D products' evaluation under open innovations. Taking into account fundamental elements of the open innovation paradigm in applying the authors' approach will enable:

- the application of the proposed holistic approach as a component of an enterprise's business model;
- the ability to model and take into account elements of prognosticated market behavior of a R&D product (a level of diffusion, convergence, the multiplier effect, etc.) and demand for it (particularly, it is expressed in the income approach methods) in the process of establishing prices;
- the ability to substantiate the need for involving internal, as well as external (with regard to an enterprise) types of resources in manufacturing R&D products (open market information will conduce to adequate planning and using resources and, simultaneously, to adhering to a set of important rules of the circular economy);
- analysts (developers, manufacturers, etc.) can receive free access to sets of knowledge on a competitive environment in the process of evaluating R&D products. This will foster forming competitive technological and price indicators of a product;
- the extension of distribution markets of R&D products, etc.

At the expense of aggregating several methodical approaches within itself, the holistic approach allows flexible reactions to market factors, using prices for a R&D product. This will enable the undertaking of one of the major ideas of the open innovation paradigm—providing the synergy derived from creating innovations. Such synergy becomes possible in using complementary knowledge of different market actors of the open innovation process.

Unlike other famous developments in the sphere of the holistic approach, e.g., [43,44,49–55,58,77–80], the importance of this methodical work consists of a possibility of its application to a certain product or market, as well as to products of different industries and different types of markets. The application of the suggested holistic approach is universal and may require to be detailed only in order to specify results.

6. Conclusions

Pricing for R&D products is one of the most important matters in the process of their transfer, commercialization, and market launch. Efficiency of any further actions with regard to R&D products—from the utilization to diffusion—depends on the reasonability of an established price. Nevertheless, in the process of the economic evaluation of a product, evaluators deal with the large number of factors influencing commercialization and a market launch of a product. Evaluators cannot effectively take these factors into account, using well-known methods and approaches. We solved this problem, drawing on our own holistic approach. The uniqueness of the suggested approach implies receiving an opportunity to aggregate various factors impacting a product's price, as well as components for the prognostication of its market development. The approach enables taking into consideration the influence of numerous factors, which difficultly correlate between each other.

The development of a holistic approach to R&D products' evaluation for the commercialization on the example of the R&D product of the interferometric determination of the refractive index of crystalline materials in the optical range contributed to several conclusions.

1. It is substantiated that the comprehensive application of known methodological approaches to the evaluation of the R&D product for its further commercialization will allow setting a price that will satisfy all the parties to a transfer agreement with a higher level of accuracy and meet market requirements (***Hypothesis 1*** came true).

Unlike popular means of evaluating a R&D product, when only the methods of one approach are used, a holistic approach is, on the one hand, based on the actual costs and the break-even level of a R&D product; on the other hand, it determines how much the consumer is receptive to a R&D product, and, then again, how the added value of the product will develop under the influence of market effects. Taking into account these components will allow setting prices for R&D products with a high level of accuracy and compliance with the demands of the changing market.

2. It is established that the obtained prices for the R&D product do not fully satisfy all the conditions necessary for its effective commercialization and market launch (***Hypothesis 2*** did not come true).

It is experimentally proven that the application of the proposed holistic approach to R&D products' evaluation for commercialization should be supplemented by surveys and assessments of the readiness of potential customers to purchase this R&D product at a specific price. To do this, it is necessary to conduct additional research on the sensitivity of consumers to the price of a R&D product.

3. It is proven that the proposed holistic approach to R&D products' evaluation for commercialization is multifunctional. The approach can be applied to different types of economic activity, R&D products, and types of markets. The approach makes it possible to take into account the specifics of both R&D products and the markets in which their launch is planned.
4. The obtained conclusions are substantiated on the principles of the R&D product evaluation of the interferometric determination of the refractive index of crystalline

materials in the optical range. The obtained prices based on the application of a holistic approach to R&D products' evaluation for commercialization and the results of marketing research of the interferometry market testified to potential prospects of the commercialization of the R&D product and its long-term competitiveness.

Based on the conducted research, the key provisions of the concept of providing competitive advantages for the period of the project realization on the commercialization of the device of the interferometric determination of the refractive index of crystalline materials in the optical range are defined. The strategic highway of the market distribution of devices of the interferometric determination of the refractive index of crystalline materials in the optical range for the period up to 2026 should combine the following strategies: focus on low costs—2022–2024; leadership in compliance with affordable prices—2024–2026.

Our main idea consists of fostering the effective technological entrepreneurship in the era of the knowledge economy development. Therefore, results obtained in this scientific paper are characterized as those containing dual value—macroeconomic and microeconomic ones.

Applying the suggested holistic approach will provide the following advantages for facilitating the development of an economic policy:

- substantiating a range of prices and other cost indicators in a situation of making decisions concerning investment and innovative projects, especially government-funded ones;
- predicting the market development of R&D products (particularly, radical ones) with higher likelihood; this may become an element taken into consideration in a government policy of technological development;
- offering a substantiated level of value and cost indicators of R&D, as well as characteristics of their market launch, is essential in forming strategies for the development of regional innovative infrastructure since this level enables the showing of strategic localizations of technological development in a region;
- demonstrating an opportunity for the prognostication and enshrinement of complicated economic phenomena such as the convergence and diffusion of R&D products in legal documents on regional development;
- obtaining digital data in the process of this research may be characterized as data with the strict profile orientation. These data manifest realities of market development in the sphere of interferometers and interferometry with high precision and accuracy. Such outcomes may be useful for specialists of a substantive area and in the form of basic information for the further formation of development prospects in this sphere and its strategic expansion.

We may conclude that further development of the scope of study for the economic evaluation of R&D products consists of a need for: searching new methodical instruments of prognostication; applying approaches of big data analytics; forming a new perspective on the nature of contemporary business influenced by intellectualization. This will allow overcoming an existing gap between developers of R&D products and a market.

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