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Lisovska Lydia, Doctor of Economic Sciences, Professor
Lviv Polytechnic National University
*https://orcid.org/*0000-0002-9937-3784
lidia.s.lisovska@lpnu.ua
Лісовська Лідія, д.е.н., професор
Національний університет «Львівська політехніка»
*https://orcid.org/*0000-0002-9937-3784
lidia.s.lisovska@lpnu.ua

METHODS AND MODELS FOR VALUATION OF R&D RESULTS: ADVANTAGES AND LIMITATIONS

The article summarises the issues of justification and selection of methods for assessing the value of scientific and technical work (STW) results in the process of their commercialisation by universities in the business environment. The main purpose of the study is to analyse the existing methods of valuation of the results of scientific and technical works as intellectual property objects and to group them to present characteristics for practical use. Assessing the value of R&D results is one of the fundamental tasks of its effective commercialisation. A qualitative and objective assessment should be considered as the first and decisive stage in the process of forming an agreement on the transfer of R&D results. The urgency of solving this scientific problem lies in the fact that determining a "fair" price should become not only a source of compensation for the authors' efforts, but also a factor in the successful innovative development of universities. The study of the problem is carried out in the following logical sequence: first, the methods and models for determining the value of R&D results are analysed, and then a comparative analysis of the advantages and limitations of their use for different types of R&D results and innovations is carried out, respectively. The methodological tools used in the study were: systematic approach, methods of analysis and synthesis, historical, logical generalisation, comparison, etc. The object of the study is the methodological and methodological approaches to assessing the value of the results of scientific and technological development, and the subject is the justification for choosing the optimal method for the established assessment goals. The study systematises models for assessing the value of the results of scientific and technological research. These are: asset-based models; models based on cost analysis; models based on competitive analysis; models based on income analysis; models based on value analysis. The study confirms and theoretically proves that the model that will not be limited to the unambiguous determination of the value of the R&D results, but will provide at least a two-level assessment of the value (minimum and maximum value), which would allow to determine the level of commercial potential of the R&D results. Such an approach would enable the university and the consumer of the results of the R&D to develop and implement measures to improve the state of affairs with this R&D, bringing its value assessment closer to the desired value. The results of the study may be useful for researchers, entrepreneurs, civil servants, university professors, graduate students, specialists of technology transfer centres or similar units of universities, auditors, technology assessors, managers of various institutional levels.

Key words: *R&D results, readiness assessment, cost estimation, estimation models, estimation methods.*

МЕТОДИ І МОДЕЛІ ОЦІНЮВАННЯ ВАРТОСТІ РЕЗУЛЬТАТІВ НАУКОВО-ТЕХНІЧНИХ РОБІТ: ПЕРЕВАГИ ТА НЕДОЛІКИ

У статті узагальнено питання обґрунтування та вибору методів оцінювання вартості результатів науково-технічних робіт (НТР) в процесі їх комерціалізації університетами у бізнес-середовище. Основною метою дослідження є аналізування діючих методів оцінювання результатів науково-технічних робіт як об’єктів інтелектуальної власності та їх групування для представлення характеристики з метою практичного використання. Оцінювання вартості результатів НТР є одним із засадничих завдань її ефективної комерціалізації. Якісне та об’єктивне оцінювання потрібно розглядати як перший і визначальний етап у процесі формування угоди про трансфер результатів НТР. Актуальність вирішення даної наукової проблеми полягає в тому, що визначення «справедливої» ціни повинно стати не лише джерелом компенсації зусиль авторам, але й чинником успішного інноваційного розвитку університетів. Дослідження проблеми здійснено в такій логічній послідовності: спочатку проаналізовано методи та моделі визначення вартості результатів НТР, а потім проведено порівняльний аналіз переваг та обмежень їхнього використання для різних видів результатів НТР та інновацій відповідно. Методологічним

інструментарієм дослідження слугували: системний підхід, методи аналізу й синтезу, історичний, логічного узагальнення, порівняння та ін. Об'єктом дослідження обрано методичні та методологічні підходи оцінювання вартості результатів НТР, а предметом – обгрунтування вибору оптимального методу за встановленими цілями оцінювання. У дослідженні систематизовано моделі оцінювання вартості результатів НТР. Це: моделі на основі активів; моделі на основі витратного аналізування; моделі на основі конкурентного аналізування; моделі на основі доходного аналізування; моделі на основі вартісного аналізування. Дослідження підтверджує та теоретично доводить, що перспективною є та модель, яка не обмежуватиметься однозначним визначенням вартості результатів НТР, а забезпечить принаймні дворівневу оцінку вартості (мінімальне та максимальне значення), що давало би змогу визначати рівень комерційного потенціалу результатів НТР. Такий підхід надаватиме можливість університету та споживачеві результатів НТР розробляти і впроваджувати заходи щодо покращення стану справ із цією НТР, наближаючи її вартісну оцінку до бажаного значення. Результати дослідження можуть бути корисними для наукових працівників, підприємців, державних службовців, викладачів закладів вищої освіти, аспірантів, фахівців центрів трансферу технологій або аналогічних підрозділів університетів, аудиторів, оцінювачів технологій, менеджерів різних інституційних рівнів.
Ключові слова: *результат науково-дослідних робіт, оцінювання готовності, оцінювання авартоті, моделі оцінювання, методи оцінювання.*

Statement of the problem in a general form and its connection with important scientific and practical tasks. Estimating the value of R&D product results is one of the fundamental tasks of its effective commercialization. Qualitative and objective assessment should be considered as the first and determining stage in the process of forming an agreement on the transfer of R&D product results. The problem of commercialisation of the results of scientific and technical work (STW) in Ukraine is an urgent and pressing one. Over the past decade in Ukraine, it has been in the focus of universities, institutions of the National Academy of Sciences of Ukraine, society, governments, parliaments, private business, and scientists themselves, and this is no accident. After all, it is commercialisation that determines the viability of R&D results and, ultimately, allows the author or team of authors to receive compensation for their efforts. Such compensation is ensured on the basis of a reasonable choice of the method for assessing the value of R&D results. There is a need to revise the current approaches to assessing the value of R&D results, taking into account both market changes and the changing strategic role of the university in the region's innovation infrastructure.

Analysis of the latest research and publications, which have begun to solve this problem. The world has developed a number of documents that regulate general approaches to assessing the value of R&D results. Among the main ones are the International Valuation Standards (IVS) and European Valuation Standards (EVS) groups of standards. The decisive role of these groups of standards is due to the fact that they are part of the international legislative and regulatory framework (Directives and Regulations of the European Union).

The results of scientific and technical works are considered as objects of intellectual property (IP) in scientific studies. This fact is quite justified by a number of parameters of usefulness and purpose.

Generally, approaches to IP valuation are divided into two categories: quantitative and qualitative valuation (Intellectual Property Valuation, 2023). According to the World Intellectual Property Organisation, the principal methods for valuing IP assets are: Income method, Market method, Cost method (World Intellectual Property Organization, 2023).

IP valuation is not only the most complex and controversial aspect of what intellectual property valuation firms do, but also the area where the most significant planning and optimization opportunities exist. The following are some tips for IP asset management and valuation: Be pragmatic and rational. Evaluate the potential outcomes. Expect valuations to be disputed. Seek expert guidance (Intellectual property valuation, 2023) **.**

Factors influencing IP Valuation a. Premise of value : b. Standard of value: c. Reasons for, or purpose of, the valuation d. Time or date of valuation e. Access to and reliability of relevant data and information f. Valuation method(s) applied and assumptions made while applying (World Intellectual Property Organisation, 2023).

Universities are the main source and subject of development and commercialisation of R&D results. In recent years, there has been increasing pressure on Universities to shift from focusing primarily on teaching and performing research, and to add an equivocal Third Mission (TM), labelled "a contribution to society". Unprecedented challenges have been redesigning the missions of Universities, which are often perceived as being at a crossroads. The TM is a multidisciplinary, complex, evolving phenomenon linked to the social and economic mission of Universities in a broad sense (Compagnucci, L., & Spigarelli, F., 2020).

The emergence of Industry 4.0, also called the fourth industrial revolution, has completely changed the tasks of universities and the importance of their interaction with business. The emergence of Industry 4.0, also referred to as the fourth industrial revolution, has entirely transformed how the industry or business functions and evolves. It can be attributed to its broadening focus on automation, decentralization, system integration, cyber-physical systems, etc (Mian, S. H., Salah, B., Ameen, W., Moiduddin, K., & Alkhalefah, H., 2020). Universities generate flows of knowledge and information that it transmits to the external environment.These knowledge transfer activities of universities can be extremely diverse ranging from engagement activities such as collaborative research, contract research, consultancy through to commercialisation activities associated with patenting and academic entrepreneurship (Perkmann et al. 2013).

Although much academic research has concentrated on the outputs associated with the creation and commercialisation of intellectual property, broader engagement activities may be a more valuable source of knowledge transfer to the private sector, and also a significant form of income for universities (Schaeffer et al. 2018).

The knowledge residing in universities is potentially an asset with global reach, and policymakers and university knowledge transfer offices and programmes should give careful consideration to the provision of the most appropriate mechanisms for ensuring its effective flow (Huggins, R., Prokop, D., & Thompson, P., 2020).

Three fundamental factors within universities—namely, management mechanism, innovation climate, and reward system—are identified as critical antecedents of UIC funding and universities' technology innovation performance (Tseng, F. C., Huang, M. H., & Chen, D. Z., 2020).

Technology transfer combined with firm-university-institute cooperation is one of three particular combinations, that can explain the high level of product innovation (Xie, X., & Wang, H., 2020). Transfer pricing is critical for organizations as it directly impacts an organization's cost, revenue, and profitability (Kumar, S., Pandey, N., Lim, W. M., Chatterjee, A. N., & Pandey, N.2021).

At the same time, scientists note that applying the arm's length pricing principle for calculating transfer pricing may be difficult for unique goods and services, and thus, other measures such as marginal or opportunity cost for manufacturing the product or creating the service can be considered for calculating transfer price (Holmstrom & Tirole, 1991).

Objectives. The aims of the article are to analyse the problem of assessing the value of R&D results, to identify methods for assessing the value of R&D results and to group them by a number of features for systematisation.

Methodology and research methods. The methodological tools of the study were the following approaches and methods: systematic approach, methods of analysis and synthesis, historical, logical generalisation, comparison, etc.

Presentation of the main research material with full justifycation of the scientific results. Estimating the value of scientific and technological progress results obtained at universities is necessary for various reasons, in particular for: determining the real value and market value of R&D product results; crediting the results of scientific and technological progress to the University's balance sheet and in connection with the implementation of various operations; determination of the amount of compensation in case of violation of the exclusive rights of the owner of the object of intellectual property rights (IP), which must be paid to the owner in respect of whom the rights are violated; attracting IP to investment and innovation projects; determination of the value of exclusive rights transferred on the basis of contracts for the right to use IP; transfer of exclusive rights to IP on bail; expanding the sales market and providing a franchise, etc.

Evaluation processes involve performing the following tasks: study and structuring of R&D product results directly, insert the level of readiness of R&D product results by level and the ability to access information support, determination of material and non-material resources of the business entity that are necessary for the implementation of R&D product results, research and forecasting of environmental conditions and their impact on indicators and parameters of using R&D product results.

The assessment may include the following steps: description of R&D product results and their identification parameters; establishment of indicators and criteria for compliance with the criteria of consumer needs, comparison with other R&D product results; analysis of market conditions for implementing R&D product results; analysis of operating environment conditions for implementing R&D product results; assessment of the level of readiness of R&D product results according to the established parameters, and so on.

The choice of methods for estimating the value of R&D product results is a stage of the mechanism for their cost assessment. When entering into transfer transactions, R&D product results acquire the characteristics of a market commodity and should be objects of the legal framework of influence in the purchase and sale process.

Within the framework of these approaches, we have systematized models for estimating the cost of R&D product results. They are:

- asset-based models;
- models based on cost analysis;
- models based on competitive analysis;
- models based on revenue analysis;
- models based on cost analysis.

Each type of model allows you to determine the cost of R&D product results in a certain way and has a number of appropriate methods (table. 1). Let's consider the conditions and features of using models and methods for estimating the cost of R&D product results.

The asset-based valuation model has two methods: replacement cost method; recovery cost method. The model above is based on the principle of replacing existing assets and involves calculating the cost of reproducing or replacing the valuation analogue. Methods of the asset-based valuation model can be applied to the results of those R&D products that have a low level of technological readiness.

The cost analysis model combines the following methods: method of initial costs; method of ensuring the target profit; method of return on invested capital; method of division by components. The essence of the cost analysis model involves the use of the hypothesis that the cost of R&D product results should be based on the amount of total costs incurred by developers for its creation (development). It provides for the calculation of such an amount of funds that compensates the developer for the cost of time and resources during the period of work.

Table 1. Models for estimating the cost of R&D product results*

№ з\п	Evaluation models and methods	Evaluation methods	Features of using models	Principles of using models	Recommended use at levels of readiness of R&D product results			
					R tech	R mark	Level of commercialization	Kind
I	Asset-based models.	Replacement cost method. Recovery cost method.	R&D product, designed to replace R&D product.	Substitution	4–9	2–9	Allows you to justify the planned profit taking into account environmental factors implementation.	Process R&D, improving R&D, modifying R&D.
II	A model based on cost analysis.	Output cost method; Method of ensuring targeted profit; Method of return on invested capital; method of separation by component.	Usage is based on the accuracy of the estimate.	Rationality and cost validity.	1-9	1-9	Allows you to specify the planned profit, taking into account moral depreciation.	For all types of results.
III	A model based on competitive analysis	competitive pricing method; sales comparison method.	If the appropriate conditions are met, the method allows you to select the most accurate, so-called fair, price through comparison operations.	Principles of the market environment. The principle of utility.	1–9	5–9	Allows you to improve the accuracy and objectivity of the target result.	For all types of developments, if there is competition.
IV	Model based on revenue analysis	direct capitalization method; excess profit method; method of discounting cash payment flows; royalty exemption method; the "25% rule" method PSM (price sensitivity measurement) method; multiplier method	Use in the context of projected market development.	Principles of expectation.	7–9	7–9	Allows you to improve the accuracy and objectivity of expected revenue indicators.	- For product innovation; - for technological innovation.
V	A model based on cost analysis	PSM (price sensitivity measurement) method; multiplier method	Various stakeholders should be involved in the value assessment	The principle of waiting for the value of use ((operation)	5–9	3–9	Allows you to improve the accuracy and accuracy of expected effects	- For consumer products; - for technological results; - for results with non-economic effects.

Source: developed by the author

If the price of R&D product results when using this model is set at a level that exceeds the market value of an analogue of the development result, then there will be no demand for such a product. Therefore, it can be argued that the difference between the cost established by

the methods of cost analysis and the market value of the R&D product result forms the value of the commercialization potential.

Describing the cost analysis model and its methods, we note that it allows us to determine the cost of R&D product results for virtually all R&D product results quite accurately, since the methods calculate how much resources are actually spent on their development.

This model is recommended for use when evaluating the cost of R&D product results at all levels of technological readiness. So, the cost analysis model is used to evaluate such R&D product results that involve commercialization directly by developers whose sales market is not sufficiently developed.

The model can also be applied to those R&D product results that have a special purpose, are made on a separate order and have no analogues on the market. The cost analysis model should be used in relation to those R&D product results that do not provide for profit, are unique (for example, can be used in the space or military spheres) and are not commercialized for a long time.

The methods of the model allow you to transfer the results of scientific and technological progress to accounting and add them to the University's balance sheet, which can significantly increase its market value. Determining the cost using this model is less risky: it is based on actual costs, and not on comparing sales of similar properties.

At the same time, the cost analysis model is not always effective, since this cost takes into account only the actual costs of developers to create R&D product results. This model is characterized by a number of shortcomings and contradictions: the book value of an intangible asset of a university never actually corresponds to its market value; cost estimation reproduces only costs; the advantages and benefits of using the R&D product result for the consumer during the established period are not taken into account; quite often there are significant complications due to the moral deterioration of the results of scientific and technological progress, especially when the product is used for a fairly long period of time (usually more than five years); the risk of obtaining economic advantages by the licensee is not taken into account; current and expected socially important aspects are not taken into account; in some cases, there are problems that the cost of creating a new R&D product does not correspond to the cost of reproducing its existing result, that is, it is cheaper to develop a new object than to restore the existing one. These aspects significantly narrow the scope and efficiency of using the cost analysis model in the cost assessment of the R&D product result.

The model based on competitive analysis involves the use of the following methods: competitive pricing method; sales comparison method.

Cost estimation of R&D product results using the methods of this model allows us to take into account the probabilistic nature of the cost of R&D product results developed in universities, which depends on a complex of dynamic factors. In particular, the study of the problems of market development of R&D product results gives grounds to conclude that their market value should be determined taking into account market categories, namely: supply, demand, competition and other market factors that directly or indirectly affect pricing processes with specific price-forming factors. Among them, it is necessary to highlight a "fair" assessment of the value of the results of scientific and technological progress and note that the market value implies the amount of funds that can be obtained with the most effective (from the point of view of profitability for the University and the buyer) use of this good (Lisovska L., Mrykhina O., Dzyubyk A., Terebukh A., 2020).

The revenue analysis model uses the following methods: direct capitalization method; method of excess profit; method of discounting cash flow flows; royalty exemption method; “25% rule” method.

Using the model assumes that the main factor determining the cost of R&D product results is income as a set of economic benefits that can generate results. The greater the income that is expected in the process of using the results of scientific and technological progress, the greater the value of their market value.

The essence of the model methods based on revenue analysis is to predict future income from using the results of scientific and technological progress for a certain period of time for the consumer, followed by the conversion of these incomes into the value of the object. In addition to the amount of economic benefits, you need to take into account the duration of the income generation period when analysing it.

The methods of the model are based on the principle of consumer expectations for providing income in the market environment when the conditions of the consumer's operating environment are met.

The complexity of using the model lies in the fact that the analysis conclusions are based on the difficulty of isolating from the cash flow created from the use of R&D product results, the share that can really be considered a consequence of their use. Thus, the described methods of the revenue analysis model are used to determine the cost of those R&D product results, the expected benefits from the use of which can be measured in cost units.

However, significant limitations in the use of these methods arise due to the complexity and subjectivity of accounting for economic instability in particular and inflationary processes in general. These difficulties make it conditional to forecast cash flows and discount rates. In addition, determining the economic benefits of using the results of R&D product progress is complicated by the need to eliminate the impact of other factors on the resulting indicator. Thus, these methods are based on the allocation of profit advantages that are capitalized (reduced to the present value), and the resulting value is taken as the cost of R&D product results.

The revenue analysis model allows us to estimate the value of R&D product results as the present value of future economic income associated with owning development results over their expected service life. Determine the price by calculating the current value of projected future benefits. Economic income sometimes includes cash receipts received through the implementation of R&D product results, in particular royalties, as well as cost savings in the production of products using this R&D product. Different valuation methods will depend on the nature of the intangible asset, on the sustainability and nature of income, and on the objective conditions and circumstances of consumption of the technological product.

The application of the methods of this model is based on determining: the amount of profit associated with the assets being evaluated; capitalization rates that take into account the risk associated with the profitability of the corresponding R&D product results, and the final economic life of their service life. This approach is based, among others, on the principle of participation: the subject, acquiring an additional resource in the form of scientific and technological progress results, expects to receive additional income from their use in its own operating environment. This additional income is part of the total income from using a set of other resources.

In general, the model based on revenue analysis is universal, theoretically justified and allows you to determine exactly the value of the results of scientific and technological progress (market, investment, etc.), which should be set in accordance with the type of transaction performed and the purpose of evaluation. The main disadvantage of the model methods is the difficulty of obtaining the necessary initial information for evaluation. It is then that the model based on revenue analysis requires the greatest qualification of experts for widespread use in determining the cost assessment of R&D product results.

The cost analysis model uses the PSM method and the multiplier method. *The PSM ("price sensitivity measurement")* method allows us to justify such a price range that will be considered acceptable for selling R&D product results by most experts. A reasonable price is considered "not too high and not too low". *The multiplier method* allows you to evaluate the results of scientific and technological progress by using certain coefficients that reproduce significant parameters of market analogues. Such coefficients reflect the relationship between the market value of R&D product results and the economic base (a factor expected to be obtained from the use of the development).

To calculate the cost of R&D product results, it is advisable to use interval multipliers. Interval multipliers include the following cost ratios:

1) price/profit;
2) price/cash flow;
3) price/revenue from sales.

Using the multiplier method means that as a result of the calculation, there will be several options for the cost of R&D product results. For each multiplier, its own weight coefficient is determined and by weighing, the value of the cost of R&D product results is calculated, which is the basis in the process of concluding contracts.

The practical use of each method from the described models mainly leads to obtaining different values of the value of the object being evaluated, since it takes into account the technical and economic characteristics of the results of scientific and technological progress in different ways.

For a reasonable determination of the value of the R&D product, it is advisable to take into account the level of technological readiness at which it is located (Lisovska L., Chukhray N., Shakhovska N., Mrykhina O., Bublyk M., 2019; Parasuraman A., 2000; NASA, 2017).

The analysed practical experience in the cost assessment of R&D product results shows that the development of combined methods for taking into account all factors can give a significant economic effect in the case of commercialization of R&D product results. The most popular option for a combined approach is an organic combination of several. The peculiarity is that the estimates obtained using these methods are compared by the buyer and seller, weighing the corresponding results, that is, assigning weighting factors, taking into account factors: the reliability of the initial information, the number and nature of hypotheses accepted, in particular when predicting future income.

After performing the analysis, it can be argued that a promising model is one that will not be limited to an unambiguous determination of the cost of R&D product results, but will provide at least a two-level estimate of the cost (minimum and maximum values), which would allow determining the level of commercial potential of R&D product results. This approach will enable the University and the consumer of R&D product results to develop and implement measures to improve the state of affairs with this R&D product, bringing its cost estimate closer to the desired value.

Since R&D product results are unique objects with their own key utility parameters and factors of effective use, it is advisable to justify and choose the model and method for evaluation in each case separately.

Conclusions, discussion and recommendations. The main idea of all models boils down to the fact that first the University transfers the developed technology in the form of development documentation to the Technology Transfer Centre created under it; based on the assessment of the transferability of the Technology Transfer Centre technology, it determines the best option for its transfer and commercialization.

The choice of a model for commercialization of R&D product results is based on market forecasting, that is, forecasting changes in each of the business entities in the market that are associated with the process of transfer and commercialization of R&D product results, trends and market specifics. Forecasting the results and consequences of choosing a particular option for commercializing R&D product results from universities to the business environment allows you to get possible estimates of certain parameters studied, taking into account the future development of the R&D product result, evaluate changes in the external environment, and quickly respond to these changes.

Taking into account the objective integration of Ukrainian innovation into the world space, but taking into account the differences inherent in the modern domestic research sphere, we consider it appropriate to take as a basis the world's advanced methodological approaches to technology assessment and take into account the specifics of National Innovation Progress.

Author contributions
Conceptualization: Lidiya Lisovska
Data storage: Lidiya Lisovska
Formal analysis: Lidiya Lisovska
Acquisition of financing: Lidiya Lisovska
Investigation: Lidiya Lisovska
Methodology: Lidiya Lisovska
Resources: Lidiya Lisovska
Supervision: Lidiya Lisovska
Confirmation: Lidiya Lisovska
Visualization: Lidiya Lisovska
Written by: Lidiya Lisovska

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