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The Value of Knowledge in the Age of the Knowledge Economy

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Abstract. In today's infocommunication and digital world, the value of knowledge has become as important as the cost of innovative products or services. Knowledge itself is now a commodity in the era of the knowledge economy. Accurately determining the cost of knowledge has emerged as a critical area of research for both science and business. This study aims to identify the distinctive features of the knowledge economy era and to mathematically formalize the cost of knowledge. The research employs a systematic analysis of scientific knowledge in the field of the knowledge economy. The results include a methodology for calculating the maximum cost of knowledge, which depends on several factors: the size of a realistic achievable market segment (SAM – Serviceable Available Market); the prevalence of knowledge in society's educational sphere; the level of understanding required by the user; changes in the comfort of human life; the innovativeness of knowledge; and the speed at which new innovative knowledge is created. The study also explores the impact of infocommunication knowledge networks on production sustainability. It demonstrates that the growing importance of knowledge in national and global economies represents a new innovative revolution, driven by computer technology, digital infrastructure, and highly skilled labour. The key conclusion is that effective knowledge management and the development of infocommunication knowledge networks are essential strategies for the successful growth of modern companies.

Keywords: innovation, open economy, knowledge economy, production function, cost of knowledge

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ЭКОНОМИКА ЗНАНИЙ

ОРИГИНАЛЬНАЯ ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ
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Ценность знаний в эпоху экономики знаний

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Аннотация. В современном инфокоммуникационном и цифровом мире актуальным вопросом является не только стоимость инновационного товара или услуги, но и стоимость знания, которое также становиться в эпоху экономики знаний товаром. Определение более точных стоимостных показателей знания является актуальным направлением науки и бизнеса. Целью исследования является определение отличительных черт возникновения и существования эпохи экономики знаний, математически формализовать стоимость знания. Основным методом анализа является систематизация научных знаний в области экономики знаний. Результатами являются методика расчета максимальной стоимости знания, которая зависит от: объема реалистичного достижимого сегмента рынка (SAM – Serviceable Available Market); распространённости

знаний в образовательной сфере общества; требуемого уровня познания знания пользователем; изменения комфорта жизнедеятельности человека; инновационности знания; скорости создания новых инновационных знаний. Представлены аспекты влияния инфокоммуникационных сетей знаний на устойчивость производства. Показано, что растущая важность знаний в экономике стран приравнивается к новому инновационному развитию государства, основанному на компьютерных технологиях, цифровой инфраструктуре и высококвалифицированной рабочей силе. Основной вывод исследования состоит в подтверждении гипотезы о том, что эффективное управление знаниями и создание инфокоммуникационных сетей знаний являются главной стратегией современного успешного развития компании.

Ключевые слова: инновации, открытая экономика, экономика знаний, производственная функция, стоимость знания.

Информация о финансировании: Данное исследование выполнено без внешнего финансирования.

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INTRODUCTION

Several scholars have characterized the importance of knowledge in the economy as a new industrial revolution, often referred to as the knowledge economy or the new economy. This transformation is based on computer technologies, digital infrastructure, and a highly skilled, technologically literate workforce (Sukharev, 2024a; Sukharev, 2024b). In the business world, knowledge is considered the most valuable asset and requires effective management, as well as support, preservation, and protection measures. In advanced states at their current stage of development, knowledge functions as a production factor and is no longer merely a residual element of technology within the production function (Sukharev, 2015). However, scholars often approach the value of new knowledge in abstract terms, relying on qualitative measurement scales. The value of knowledge is primarily determined by how quickly it is disseminated and localized through infocommunication networks. These networks are increasingly regarded as essential for addressing economic, social, and other systemic challenges. Considering standards, organizational frameworks, consumer requirements, and scientific evidence, the economic dimension has become an integral part of corporate activity nationwide. This study hypothesizes that effective knowledge management and establishing infocommunication knowledge networks are crucial and timely strategies for integrating external economic factors into corporate processes.

The relevance of this study stems from the expansion of the global information and knowledge economy, coupled with insufficient production capacities of the states to secure sustainable development. This study aims to identify the distinctive features of the knowledge economy era and provide a mathematical formalization of the cost of knowledge. This investigation is motivated by the potential contribution of the knowledge economy to addressing production and economic challenges, particularly through developing infocommunication knowledge networks for sustainable production. These networks should remove barriers to safe production practices and promote the dissemination of knowledge about economic, social, and technological problems and their solutions.

The impact of the knowledge economy on national economic development

Economic development encompasses the evolution of the agricultural, industrial, informational, and other sectors. It is defined by transitions to new historical epochs that bring fundamental changes to the organization of work and community life. Although economic and political aspects of state development may reinforce one another, they should not be conflated. Agricultural and industrial evolution was always rooted in technological knowledge transformations (Stearns, 2013; Landes, 2003). Additionally, industrial growth generates continuous and cumulative technological and

scientific progress (Landes, 2003; Clark, 2014). In the contemporary period, industrial development is rooted in innovations and know-how stemming from advances in various scientific fields. The continuous pursuit of technological progress invariably initiates processes of technological change in human activity and community life. This dynamic distinguishes the modern model of development from sporadic innovations that occurred in European and North American countries a century or more ago (Landes, 2003).

Industrial development has profound economic and social consequences, reshaping consumer, financial and raw material markets, and necessitating new organisational models for corporations and their functions. This includes new methods of market research, marketing and digital marketing. It also transforms the way the state allocates financial and material resources, advances credit and develops transport and educational structures (Landes, 2003). At the same time, qualitative leaps in industrial development do not occur within short timeframes, but rather unfold over several years or decades. Therefore, it is impossible to establish precise boundaries for the beginning and end of a specific stage of economic development. However, such stages can be represented as a set of processes (Stearns, 2013). These include enhancing machine power and efficiency, increasing production automation, and speeding up its diffusion across industry, as well as continuously growing technological and scientific progress.

The informational development of the state operates with compatible and inseparable concepts, namely information and knowledge. The meaning of these concepts may change at different stages of informational development, thereby altering the notion of the knowledge economy. The knowledge economy is primarily based on the high-technology sector, where technological innovations alter the nature and scale of knowledge production (Sukharev, 2020; Sukharev, 2023). In this economy, it is the production of ideas rather than goods that drives economic growth and improvements in quality of life, with information and telecommunication technologies sustaining and enabling such development (Neef, 1998).

Infrastructural technologies are the main way that ideas are shared, so they should be seen as the basis of the knowledge economy. New knowledge and research outcomes, including know-how, patents, scientific publications, technical drawings and other formats, can be disseminated rapidly around the world. The internet and information communication networks have dismantled barriers of time, cost and distance, ushering in an era of global information connectivity. These networks contribute significantly to the globalisation of the economy by enabling companies to access new markets and production resources. Consequently, less developed countries may be able to generate knowledge and embark on a trajectory of rapid economic growth by strengthening their national scientific potential.

The informational development of the state redistributes labour resources from other sectors of the economy into the service sector. In an information society, over 85% of the population works in services, with 65% employed in high-technology fields (Sun et al., 2019). The changing composition of the labour market is the most reliable indicator of continued informational development, with fewer and fewer people employed in manufacturing industries. In the knowledge economy, the encoding of information in software (codification) and the collection of information and knowledge from the environment are intensifying. Ultimately, all data relating to physical objects, people, processes and organisations will be accessible via public infocommunication systems. In such a scenario, the world will be represented by information bytes. Human interaction with the world could be substantially enhanced and made more comfortable if sufficient computational capacity were available in electronic computing technology.

For knowledge-based companies, such as those involved in software development, the changes may be substantial, since, unlike firms in traditional sectors, they are not geographically constrained. A knowledge-based economy encompasses electronic commerce, global

networks, extended enterprises, and the trade of knowledge, in which a company intellectual capital can be combined, purchased, and sold. Together with globalisation and the transition to high-technology services, this impact on the economic environment may prove transformative, even revolutionary, as companies founded exclusively on knowledge have the potential to disrupt the traditional business model of commercial activity.

Currently, the informational development of the state is still in its infancy, as technologies such as the metaverse, optical computing and quantum computing have yet to become part of everyday life. The new knowledge economy is evolving as a complex system characterised by reinforcing events that have already led to, and will continue to lead to, major leaps and exponential transformations in economic relations (Coyle, 1998; Coyle & Manley, 2024). Founded on the expansion of the service sector rather than manufacturing, the knowledge economy reflects a shift in the balance between physical and non-physical products, as evidenced by the decline in the global value of goods. This does not imply a decrease in the absolute volume of output: rather, the share of goods in economic activity declines relative to services, particularly in information- and knowledge-dominated sectors (Coyle, 1998; Coyle & Manley, 2024). Companies may produce goods more efficiently or employ innovative technologies through information and computer systems and knowledge management. Knowledge-based information technologies contribute to reducing material consumption by enabling better choices and more substantiated decisions, as well as systems of reuse (recycling), which require automated dispatching and controlled information flows.

In the knowledge economy, knowledge is the key economic variable, sustained by information technologies. This underpins the transition to a dematerialised economy with reduced physical mass. This raises the question: what is the cost of knowledge?

This question will be addressed in the following sections of the article.

The value of knowledge in the knowledge economy

In the traditional economy, the value of a product or service is clear since costs and output can be measured. However, knowledge is neutral with respect to economic systems, as evidenced by the reliance of companies on a static and unchanging body of knowledge (Mohaghegh et al., 2024; Bontis et al., 2018). In this sense, knowledge represents the residual value of the production function.

In the knowledge economy, knowledge is an increasingly important production factor (Arrow, 1999). It constitutes an economic asset that should be managed within organisations to enhance production (Kogut, 2010; Regnйr & Zander, 2014; Yildiz et al., 2020; Bontis et al., 2018). As an economic resource, knowledge can be acquired from outside the organisation and applied internally. This means it can be shared and sold as a commodity (Saadet & Karadenizli, 2024; Lee et al., 2023). Consequently, the value of knowledge must be considered not only as a local asset, but also as a global asset that encompasses the transfer of local knowledge to the global sphere and its subsequent return to the local level. Within the knowledge economy, a knowledge market exists, comprising buyers, sellers, and brokers. Buyers seek solutions to complex or uncertain problems. Sellers possess knowledge of processes or specific problem domains. Brokers establish connections between buyers and sellers, aiming to understand corporate demands and identify relevant sources of knowledge. Knowledge markets operate with a pricing system based primarily on reciprocity and reputation (Saadet & Karadenizli, 2024; Lee et al., 2023).

During the era of industrialisation (the Industrial Revolution), the generation of scientific or technical knowledge was costly, whereas its transmission was almost free. Such knowledge could be used by companies without diminishing the ability of other firms to do the same, and was therefore regarded as a public good (Arrow, 1999). This concept is particularly applicable to fundamental research, which merely provides the initial information for subsequent

inventions (Mowery & Rosenberg, 1989). However, if companies cannot benefit from the revenues of their investments in creating basic knowledge, insufficient new knowledge will be produced (Dosi & Virgillito, 2021).

Another factor influencing its cost is the prevalence of information. Once information has been transmitted, it can be reproduced at virtually no cost. If information is considered a public good, it is only valuable to users who can access it freely. However, all property rights remain in the public domain and the supplier of knowledge does not appropriate anything from the information created. At the same time, once information has been viewed, it may lose much of its value for the recipient, since buyers always face the question of how they can know whether purchased information is useful until they have examined it. Once the buyer has seen the information, its content is fixed and it loses its value (Shapiro & Varian, 2008). This means that knowledge can be easily acquired or absorbed.

Using scientific and technical information is costly and is often a itself a knowledge-intensive process. The mere availability of information does not guarantee its effective application in economic relations or its realisation in practice. Knowledge is often difficult to systematise and transmit in a form that other users can understand; in other words, a certain level of expertise is required to comprehend it. Furthermore, knowledge is not independent of its context and cannot simply be extracted and transferred between different entities. Instead, it is localised and embedded within a particular practice to a greater or lesser extent, which makes it difficult to transfer to another context (Brown & Duguid, 2001). The distinction between information and knowledge largely determines the ease or difficulty of knowledge transfer. Knowledge usually requires a bearer of knowledge (Brown & Duguid, 2001). In contrast, information is usually considered a self-contained entity and is therefore easier to separate. However, codified knowledge must be processed and systematised in order to be transmitted effectively to other users. Knowledge necessarily requires assimilation; individuals must analyse, understand, and potentially apply it (Brown & Duguid, 2001; Rikap & Lundvall, 2022; Lundvall, 2022).

If knowledge is difficult to transfer to the user, its value increases. The value of knowledge also depends on preventing its leakage from the local environment into the general environment (i.e. minimising public ownership); in other words, the value of the knowledge economy lies in both its dissemination and localisation. To ensure the secure transfer of knowledge, a specially configured knowledge network is required (Choucri & Agarwal, 2022; Ramirez & Choucri, 2016). Infocommunication networks, particularly the Internet, are the primary tools for storing and managing information. Information and knowledge can be disseminated worldwide and made accessible through various software and hardware interfaces. Digital technologies have transformed networks into the primary locations where information and knowledge are stored and where people communicate and engage in economic relations with one another. However, in order to achieve the complete and effective commercialisation of knowledge through knowledge networks, the following questions must be addressed:

- What infocommunication technologies should be developed, and what pricing system should be established?
- Which marketing and digital marketing technologies need to be invented or improved to increase the value of knowledge?
- Which SEO (Search Engine Optimisation) and infocommunication technologies should be used to organise and present knowledge on any issue in a way that is both useful and valuable to the user?

Knowledge within knowledge networks can be consolidated into specific clusters, enabling it to be used more effectively as input data for creating further knowledge, which can also be clustered. This consolidation process establishes an efficient cycle of knowledge generation. When a greater number of people uses a particular body of knowledge, it does not diminish in value, but instead increases significantly as it becomes a standard that ensures the comfort

of human activity and simultaneously generates additional knowledge.

The value of knowledge can be expressed as a mathematical function of the parameters of human comfort and the rate at which new knowledge is created. These parameters can be characterised using qualitative indicators, which can be converted into quantitative measures by applying methods from the mathematical theory of fuzzy sets. Unlike other studies, this article proposes a faster and more precise method of determining the rate of new knowledge creation using data on the number of patents across different fields of knowledge. Knowing the number of prototypes in invention patents, the number of recurring prototypes across different patents, and the time of patent registration makes it possible to calculate the minimum, maximum, and average rates of new knowledge creation. However, it must be recognised that such standards change over time and therefore the value of knowledge will also change.

Based on the aforementioned, it can be concluded that the maximum value of knowledge, denoted by the parameter Cmax, is determined by the size of the realistically attainable market segment (SAM – Serviceable Available Market). The volume of the TAM (Total Addressable Market) cannot be taken into account when defining the value of knowledge since the price of knowledge demand is formed at most at the level of the corporation, which in turn defines the SAM parameter. The value of knowledge is influenced by the following factors:

1. The dissemination of knowledge within educational sphere of the society can be represented by the K_p index. The higher the dissemination of knowledge, the lower its value. When knowledge is accessible at the level of secondary school or college (in reference to the Russian education system), K_p = 0. When knowledge is accessible at the level of higher education institutions, K_p = 0.3. When knowledge is accessible at research institute level, K_p = 0.7. When knowledge is accessible at an academic level (closed research laboratories of the Academy of Sciences), K_p = 1.0.

2. The required level of knowledge acquisition by the user (potential producer) can be represented by the index K_k. The higher the level of complexity in acquiring knowledge, the greater its value. If knowledge can be acquired on the basis of secondary school or college education, then K_k = 0. At the level of higher education, K_k = 0.3. At the level of postgraduate education (doctoral, postgraduate, adjunct, residency, internship), K_k = 0.7.

3. The index K_c is used to represent the change in human comfort of life. Human comfort encompasses various well-being indicators, including nutrition, housing, personal goods, tourism, ecology and environmental conditions, among others. It is assumed a priori that all components of human comfort are currently equivalent and that their variation is equal in absolute value to one. Knowledge may either reduce human comfort in certain areas of life, in which case K_c = −1, or enhance it, in which case K_c = 1. If the components of human comfort remain unchanged, then K_c = 0.

$$K_c = \frac{\sum_{i=1}^{N} K_{c.i}}{N},$$

where $K_{c.i}$ – the i-th component of human comfort of life; N – the number of components of human comfort of life.

4. The innovativeness of knowledge can be represented by the K_{In} index. This is determined by the presence of knowledge formalisation in the form of invention patents, as well as the volume of patents in a specific field of knowledge. The K_{In}. index is also influenced by the time elapsed since the start of the invention validity period of the patent. After one year, a patent loses its innovativeness since applications for invention patents can be filed in other countries within this timeframe.

$$K_{In} = \left(\frac{n}{N_y}\right)\exp(-2T),$$

where n – the number of patents in the past year, units; N_y – the number of invention patents in the past year, units; T – the time since

the beginning of validity of the most recently registered invention patent, years.

The field of knowledge used to calculate the K_{In} index is defined as follows: if an invention patent belongs to classification index A61B of the International Patent Classification (IPC), for example, then the field of knowledge is determined by the number of patents included in index A61B.

5. The rate at which innovative knowledge is created can be represented by the KV index. This index is calculated over a period of twenty years, as the term of validity of the exclusive right to an invention is twenty years according to Russian legislation (Article 1363 of the Civil Code of the Russian Federation). The higher the rate at which new knowledge is created, the lower its value, because in this case knowledge quickly becomes obsolete.

$$K_V = 1 - \frac{n_{p.e.20}}{N_{p.20}},$$

where $n_{p.e.20}$ – the total number of identical prototypes in invention patents for the considered IPC classification index over 20 years; $N_{p.20}$ – the total number of prototypes in invention patents for the considered IPC classification index over 20 years.

Finally, the maximum value of knowledge in an open, free market economy is defined by the formula:

$$C_{max} = SAM \cdot K_p \cdot K_k \cdot K_c \cdot K_{In} \cdot K_V.$$

Under certain economic circumstances, the following factors will influence the reduction of the Cmax parameter:

1. The complexity of knowledge dissemination. In order to transfer knowledge to the user, it must be transformed. This is necessary for a person to be able to understand and comprehend it. For example, the mathematical formalisation of quantum physics must be transformed into a language that is accessible to the public or to specialists in related fields (electronics, medicine, etc.).

2. The potential for knowledge preservation is determined by the period and cost of ensuring knowledge security.

These two factors are calculated using specific methodologies for economic relations.

Knowledge networks for sustainable production

At present, some investors regard innovation as a highly profitable option for successful businesses. To ensure constant profit growth, company management encourages companies to introduce innovations, increase productivity, enhance customer orientation, find niche markets and anticipate (or shape) the rules of market operation. Compromise analysis uses static methods which assume that the company has made all decisions with the aim of minimising costs. In a static business environment, regulation inevitably leads to increased costs. Conversely, in a dynamic business environment, competitiveness is determined by increased productivity and innovation. Targeted regulation can stimulate innovation and generate benefits that outweigh the costs of regulation. This is possible because companies do not constantly optimise processes: technical capabilities change, information is often incomplete, organisational structures are inflexible and control is difficult.

Compensation for innovation covers both products and processes. Process-related compensation can lead to increased resource productivity, reduced energy consumption, and lower material storage and processing costs.

The overall impact of a product or process on the energy system or other environments is what the life-cycle approach is designed to minimise, at least in theory. It takes into account energy-related issues and several others at each stage of the product life cycle, from material procurement to product disposal. Life-cycle analysis considers safety, health, and social factors throughout the entire service life of a product, process, material, technology, or service. In practice, however, the term refers to the quantitative analysis and assessment of material and energy costs, as well as environmental impacts.

As with any successful business strategy, an effective strategy in the knowledge economy requires sound technology management, an

understanding of market characteristics, and political awareness. Understanding the business environment requires technological infrastructure, efficient analytical methods and access to information. Those who acquire and utilise intellectual assets – namely skilled labour, business information and scientific knowledge – will gain a competitive advantage, as these assets generate knowledge for the future. This dimension may be particularly significant in the energy sector, given the new technological demands, shifting consumer attitudes and global scale of energy challenges.

A company may adopt different standards or procedures for distinct product lines, depending on its location and other contextual factors. The innovation/need for innovation parameter measures the complexity and diversity of innovation requirements, or the driving forces that underpin the development of sustainable or energy-secure technologies. The relationship between industry and society encompasses multiple dimensions, including ethical, technological, economic, and political aspects. At the lower level of knowledge development, a company primarily responds to short-term market demands for innovation. As a company advances in knowledge development, the driving forces behind the creation of new knowledge become more complex. They incorporate political factors, technological progress and regulatory structures. This is particularly relevant under conditions of globalisation. Companies operating in environments that extend beyond traditional or local constraints tend to adopt a long-term perspective, being generally forward-looking and proactive. The knowledge space may be defined by several vectors measuring different dimensions, such as geographical boundaries, problem domains, and technical aspects.

Company management must continually ask whether the knowledge required for product design and production covers the entire life cycle, from material use to disposal. The answer lies in a production model that aims to reduce, minimise, contain and control material and energy consumption. Such a model requires consideration of the entire production life cycle. In order to establish a link between the more rational use of primary resources and the creation of products or materials at subsequent stages, it is essential to have thorough knowledge of product components and their role in the production process. This requires effective coordination among all participants in a product or service value-creation chain. This model becomes fully operational when supported by an infocommunication knowledge network and a unified information system that provides key data, information, tools and knowledge to users at most levels of enterprise management.

When defining a knowledge-generation strategy, one of the key challenges is integrating diverse groups of specialist workers and scientists into a unified product or service design process. In more complex production systems, groups with different objectives and responsibilities need to be involved in the design process from the beginning to improve efficiency and competitiveness. At the same time, energy-related issues may impact various areas of product development. These challenges go beyond individual practices and create obstacles to the overall design process and achievement of energy-related objectives. Recognising and representing the complexity of sustainable production allows better assess and understanding of the role of knowledge and infocommunication technologies. Infocommunication knowledge networks can be considered as infrastructure and communication channels that facilitate the transmission of design-related knowledge throughout the entire product life cycle.

CONCLUSION

This study is motivated by trends such as the growth of the global information and knowledge economy, and the search for sustainable business solutions. The growing importance of knowledge in both the national and global economies indicate a transition to a new phase of state development based on the application of computer technologies, expansion of digital infrastructure, and utilisation of highly skilled labour. In the information and knowledge

economy, knowledge constitutes an economic asset that requires management, support and preservation. From an economic perspective, knowledge is a production factor rather than a residual element of technology within the production function.

The value of knowledge is considered through the dissemination and localisation of new knowledge via an infocommunication knowledge network based on information technologies. In the knowledge economy, the value of knowledge lies in the possibility of sharing it through an infocommunication knowledge network that disseminates, localises and generates new knowledge. A business process may also be examined from the perspective of added knowledge value. The growing importance of knowledge leads to an increase in its intensity and a transformation of its boundaries.

Infocommunication knowledge networks are regarded as an important module for addressing the energy problems of nations. Effective knowledge management and the establishment of infocommunication knowledge networks constitute the principal strategy for the successful modern development of a company.

The knowledge economy is at an initial stage of its development. However, it is already transforming labour markets and organisational structures of businesses, while also playing a significant role in creating value within national economies. At the same time, the boundaries of knowledge are merging with social boundaries, which is helping to address governmental tasks effectively, implement state social policy, provide individuals with public and private goods, and support reliable forecasting of national economic development. Open dissemination of knowledge could allow less developed countries to bypass established technologies and compete in new economic sectors.

Further research should provide a scientific description of the basic conceptual framework for knowledge exchange and the functioning of infocommunication knowledge networks, as well as the pricing of knowledge markets. This will facilitate the identification of who creates and controls knowledge, who influences it, and who derives benefit from its use. When determining the value of knowledge, it is also necessary to consider the difficult-to-formalise factor of know-how utilisation, as this likewise affects knowledge, its dissemination and its value.

Конкурирующие интересы

Автор заявляет об отсутствии конфликта интересов.

Competing Interests

The author declares no conflict of interest.

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