Modeling the long-term trend of accumulation of knowledge

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Abstract. In the given article we've developed and substantiated a model of the long-term trend of the knowledge adding process, based on the method of the production function and algebraic properties of information. We demonstrate that in terms of the increasing returns, networking specifics of production and knowledge proliferation, we face exponential growth of knowledge generation and accumulation. The development of technologies of knowledge accumulation, processing and transmission are viewed in the context of common regularities of phasic technological evolution. The given model offers the analytical kit that enables one to prognosticate the dynamics of knowledge adding effectiveness.

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Introduction

Any economy in a varying degree rests on knowledge. Production is carried out due to the interaction of proprietary factors of production, labour and knowledge, and any proprietary agent of production becomes what it is via intellect, and primordially involves a certain bulk of embodied knowledge.

Economic activity reveals a common regularity of cumulative knowledge integration. Economic activity is becoming more and more loaded with immaterial intellectual benefits as well as new technologies and knowledge. It is relevant not only to ICT, knowledge management and management intelligence systems. There also comes intellectualization of traditional commodities and services (smart homes, roads, cars, etc.)

Theory

Some scientists support the hypothesis [1, 2] that a variation number of uses of the first man-discovered natural material is small, due to the initial incompleteness of knowledge of its properties. Subsequently, along with the adding of information about the properties of the given resource, the scope of its possible uses expands. In the context of the suggested idea, it is assumed that within the scope of one leading technological set up the interlinking between the buildup of the added knowledge volume (k) and the variation number of uses of any natural resource or man-made material is reflected in the next logarithmic function: U(k) = ln k (Fig. 1). Together with knowledge accumulation, the number of possible uses goes up, but the growth itself slows down and the effectiveness of knowledge adding is reduced. In theory, there is a limit to the variation number of uses within the framework of a single technological structure, reflected in the given inequations:

$$\frac{dU}{dk} > 0, \quad \frac{\partial^2 U}{\partial k^2} < 0 \qquad (1)$$

In fact, the diagram of the algorithmic function illustrates a middle-term trend of the possible use of the resource. Considering the long-term tendency, Bhekuzulu K. suggests that in the position X_2 the volume of knowledge includes knowledge cumulated in the previous position X_1, coupled with some additional knowledge (Fig. 2), besides:

$$(U_2 - U_1) > (U_1 - X_1)$$

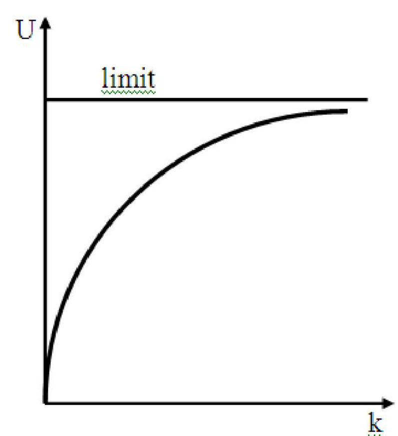

Fig. 1. The variation number of uses of the resource within the scope of one technological structure.

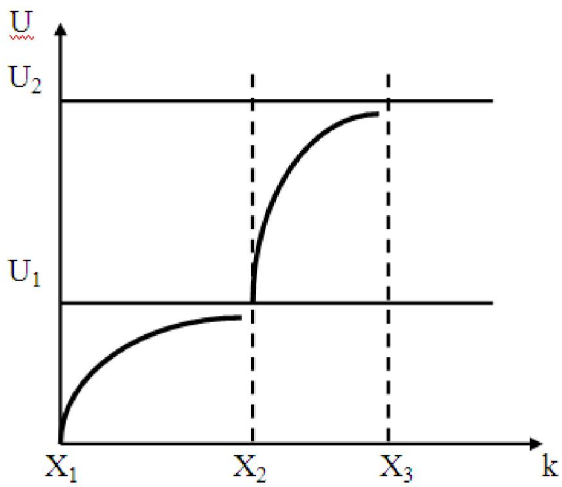

Fig. 2. The variation number of uses in the transition to the next technological structure

Therefore, in the long run, cumulative effectiveness increases. So as to make this hypothesis comprehensive enough, we suggest considering the fact, that both consumption patterns and production technologies are constantly evolving. Subsequently, some resources in the next technological structure may appear to be less useful and can possibly be replaced with the newly discovered resources, more appropriate to this structure.

If we join two points with peak value of possible uses, we can see the following trend: (Fig. 3).

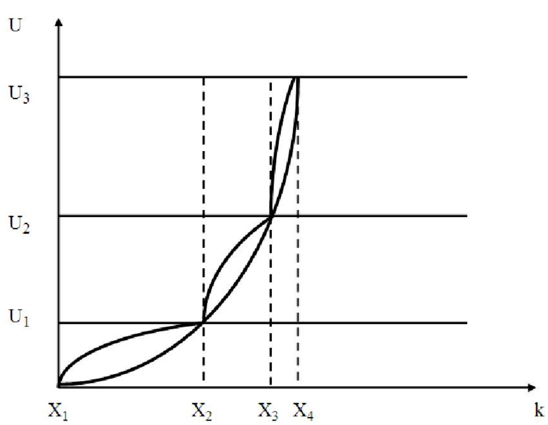

Fig. 3. The long-term trend of the variation number of uses of the resource.

Besides:

$$(U_3 - U_2) > (U_2 - U_1) > (U_1 - X_1) \quad (3)$$

According to those holding to the given hypothesis, the trajectory of knowledge integration in the long term is represented by the exponential relation with the accelerating knowledge buildup. While there is a limit to cognizance in mid-term, such limit could only be defined in theory as "society knows all" in the long-run prospect [3].

The model of the long-term exponential trend of knowledge adding is based on the proposition that the increase of knowledge is proportional to the volume of previously cumulated knowledge [4]:

$$\frac{dK}{dt} = v \cdot K \quad \text{или} \quad \frac{dK}{K} = v \cdot dt \quad (4)$$

where K is the volume of cumulated knowledge, V is the increase factor and t is the time. The differential equation of the exponential function illustrates the importance of the speed of knowledge diffusion:

$$K(t) = e^{vt} \quad (5)$$

Results

In our view, methodology of exponential growth of knowledge generation is grounded in the effect of the increasing returns effect, ensured by the positive feedback in terms of the networking specifics of production and knowledge proliferation. The possibility of exponential knowledge integration and the increasing effectiveness can be sustained through the neo-classical method of the production function:

$$Y = A\,K^{\alpha}\,L^{(1-\alpha)}, \quad (6)$$

where Y is the calculating index of production growth; A,[alfa] – productivity factor ; their specific numerical value is defined on the basis of statistical data with the help of correlation methods.

Factor A (Total Factor Productivity) indicates the level of total technological productivity. The traditional production factor of Cobb-Douglass is a CRS function, so the productivity of capital along with consumption per capita does not increase if the exogenous factor doesn't grow. To convert the A factor to the endogenous one, A.K. Arrow used a test method for the production function of an individual $firm_i$ [5, 6]:

$$Y_i = A_i K_i^{\alpha} L_i^{(1-\alpha)}, \quad (7)$$

where A_i is the analogue of TFP for each firm, but, in point of fact, can be attributed to economy in general. Along with the increase of physical capital supply, knowledge used by every firm builds up at the rate [beta] [7]:

$$A_i = T^{\beta} \quad (8)$$

In the aggregate, information adding is identical to capital saving in the national economy, that is T = K. Therefore, the aggregated production function can be illustrated as:

$$Y = K^{(\alpha+\beta)} L^{(1-\alpha)} \quad (9)$$

If we use the universal symbol for the physical and human capital (K), the equation of the capital compounding will be as follows:

$$K = K(1+\varepsilon)^n \quad (10)$$

where [epsilon] – is the factor, denoting the growth of the intellectual constituent in the capital cost, n – is the number of compounding periods. If we us the second limit and assume that [epsilon] is a low count, we could deduce a theoretical possibility of exponential increase of capital and knowledge and, subsequently, rise in production.

Many modeling constructs, illustrating the interlinking between the players of intellectual markets and information technologies, are based on L.V. Kantorovich's idea of the idem potency of addition of information, which claims that the production and consumption of one product pattern is equivalent to the production and consumption of a number of product patterns.

Commenting on the algebraic properties of information, that is the idem potency of adding information, scientists are inclined to think that represent ability of the product in the digital format means that the addition of such products is idempotent as well as the addition of information or knowledge, A+a=A. Therefore the formula A-A=A [8] is true as well. The knowledge possessor doesn't lose his knowledge when the latter is being passed on to another subject.

This property ties together the possibility of knowledge representation in the digital format and its non-competitive use. In a certain extent, exponential growth of knowledge is stimulated by information piracy, as a tool of price discrimination, when the consumer with a fairly modest income gets access to information resources and knowledge at a low or zero price.

The given exponential relation demonstrates the ideal process where the actions of business entities are rational and they act in accordance with the law of knowledge adding without any transaction costs.

In reality, there is political protectionism, promoting the interests of a certain group to the prejudice of the other. We are also faced with cross-cultural communication barriers. Knowledge, in many instances is a very politically loaded good, limited by contractual obligations.

The transition from the theoretical model of knowledge adding process to the factual one, is possible considering additional transaction costs, reducing the effectiveness of the given process. As seen in the charts (Fig. 4), there is a gap between the "ideal" and "real" knowledge. This breach was termed "potential gap" [9, 10]. Apparently, knowledge adding depends on how institutionally prepared socium is to perceive and reproduce information. The more accurately society abides by the law of knowledge, the more successful its socio-economic development will be.

However, in our opinion, the correlation, laid at the basis of the analytical constructs, is more complex and can be illustrated with a logical curve. The development of technologies of knowledge adding, processing and transmitting follows common regularities of phasic technological evolution [11, 12, 13].

During the first phase – the phase of the new technology emergence, its effectiveness is high.

During the second phase, society acknowledges the value of the new technology and its proliferation begins. During the third phase there appear controversies on the subject of technology application in view of the exhaustion of the resource the technology was based on. In the fourth stage new generation technologies, marked by higher effectiveness, crop up. The fifth stage features a drop in the scale of utilization of the old technology, which, however, is still being used in a limited degree.

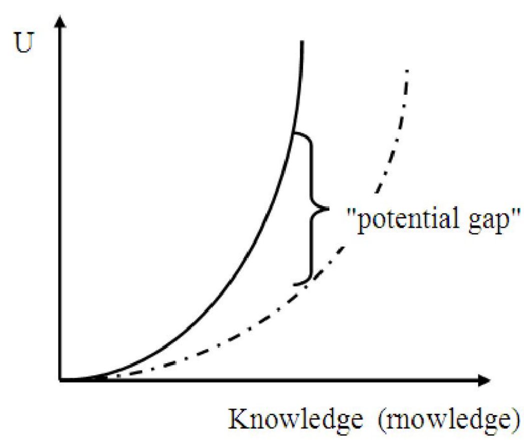

Fig. 4. Potential lagging

In the analysis of innovative technologies, scientists traditionally single out General Purpose Technologies (GPT) as intensive mass technological innovations, determining innovative cycles and fluctuations in business activity [14, 15]. Among these technologies we could find steam engine, railway communication, electric power transmission, internal combustion engine, electronic and computer technologies, Internet technologies.

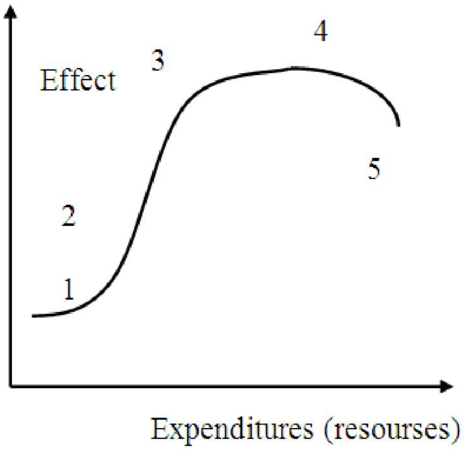

Fig. 5. Effectiveness of phases of new technologies evolution.

GPTs have a powerful potential to impact the economic dynamics and radically transform its key properties. GPTs are characterized by massive distribution, dynamism and augmentability. Spreading of GPTs on the global scale means that all machines and mechanisms adopt their mode of operation. Technological dynamism is ensured through permanent support of innovations and proper training. Labour productivity goes up as a result of consistent improvements of GPTs. By-turn, there is a certain feedback when GPTs improve Special Technologies, developed on their basis, thus revealing their innovative augmentability. However, there is a limit to GPTs improvement capacity. In the development of a new GPT there occurs an innovative gap entailing a slowdown in economic dynamics followed by a recession phase inside the economic cycle.

Conclusions

The exponential trend of the growth of added knowledge volume is explained by the fact that "over the last years the bulk of knowledge has doubled every seven months, whereas more than 5 million websites have emerged in the Internet space every day" [16, 17]. Compounded Annual Growth rate is represented in table 1 [18, 19]. Reference value CAGR supports the exponential dynamics of knowledge accumulation in the long term.

Modern science features exponential advancement of scientific knowledge and aims at its capitalization.

Integration of fundamental knowledge involves increasing expenditures for science in the developing countries, overtaxing their deficit-ridden budgets. So, prognosticating the trends of the dynamics of knowledge adding effectiveness is becoming an issue of the present.

Table 1. League table for points of measurement of the growth of human knowledge

Field	CAGR	Doubling Period (year)
Nanotechnology patents	44,91	1,87
Nanotechnology journals	42,03	1,98
Globalwarming patents	38,62	2,12
Prions patents	33,76	2,38
Programming patents	33,53	2,4
Stem Cellspatents	26,47	2,95
Prions journals	25,57	3,04
Global warming journals	24,71	3,14
Epidemiology patents	17,37	4,33
Stem Cells journals	16,63	4,51
Programming journals	12,55	5,86
Alzheimers Disease patents	11,26	6,5
Oncology patents	10,02	7,26
Alzheimers Disease journals	9,65	7,52
Oncology journals	9,23	7,85
DeSolla Price estimate of world literature growth	7	10,24
Epidemiology journals	6,22	11,49
Mars journals	5,78	12,34
Shaleoil journals	5,53	12,88
US patent grants	5,21	13,65
University enrollment world wide	4,85	14,64
Abt publications in astrophysics since 1970	4,01	17,67
US patent applications	3,88	18,21
U.S. Book publishing	3,65	19,33

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