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Forecasting the Dynamics of an Innovative Cycle

I.A. Kirshin, A.A. Datsyk and A.V. Titov

Kazan (Volga Region), Federal University, Kazan, Russia

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Abstract: The article shows and tests on statistical data a model of the dynamics of an innovative style based on using a logistic function. The model developed provides an analytical toolkit for forecasting and managing the development of innovative cycles. It is shown that the general form of trajectory of a life cycle of innovative processes it hard to use to manage their development because it only records the logic and the vector of development of these processes.

Key words: Modelling of economic dynamics . macroeconomic forecasting . innovative development . an effect of the increasing return

INTRODUCTION

The development of economic processes is subject to the law of dialectics of interaction of quantitative and qualitative changes. The transformation of the accumulated quantitative changes into a qualitative shift happens on non-linear trajectories, in the bifurcation points of which effects of the increasing and decreasing outcome substitute each other. These trajectories have disruptions that represent abrupt leap-like switches to new levels and they are quite well formalized by logical dissipative models. The ability of these models to reflect the dialectics of interactions of states of the evolutionary and revolutionary development fully refers to innovative processes.

A finished life cycle of innovations may be consistently described by a logical curve. The life cycle of innovations starts with a cumulative storage of the innovative resource (welfare). The achievement of a certain critical level of this resource generates a qualitative switch to the exponential growth of the innovative process. As the state of saturation of this resource (welfare) comes closer, there is a gradual slowing down of the speed of growth, the exponential area of the trajectory of the innovative process switches for the logarithmical one. The life cycle of these innovations finishes, the stage of folding the production and gradual departure of this resource from the market takes place.

The logic of the competitive technological shift was defined by R.Foster [1] as «S-S shift». According to his ideas, the development is possible only based on a new technological platform, graphically described by a technological disruption of SS shift. The notions introduced by him of the technological limit and technological disruption of the trajectory of development of the innovative cycle are modelled by a logistics curve. R.Foster exchanges the concept of evolutionary continuous substitution of one technology for the other one, a hypothesis of an unexpected innovation switching the previous trajectory of growth to a new logistic curve of a higher level. The economic space of any innovative process is characterized by high competition. The appearance of a competitor (technology, product or service) is possible at any site of a logistic curve. In relation to this, many researchers of technological leaps have a united opinion that a shift to a new logistic trajectory is possible and necessary also on the exponential area of the old logistic curve [2, 3].

RESULT

The general form of the trajectory of the life cycle of innovative processes is hard to use to manage its development because it only records the logic and the vector of development of these processes. Therefore, it is necessary to have a calculated model allowing determining the rate dynamics and levels of development of processes on separate segments of the logistic curve. These possibilities open up the perspective of forecasting and management of the development of innovative processes.

In the logistic model it is supposed that the time of development of an innovative process is recorded by parameter t. At the initial moment of time (t_0) the volume of innovative production is equal to zero, then, during the development process, it approaches a certain level of saturation t_1. The growth rate at different areas of a logistic function can be measured by the value of

Corresponding Author: Kirshin, Kazan (Volga Region) Federal University, Kremlevskaya, 18, Kazan 420008, Russia

its first derivative. The value of the first derivative of the logistic function Y(t) in boundary conditions of the interval (t_0, t_1) are determined by the following limits:

$$\lim_{t\to t_0} Y'(t) = 0, \ \lim_{t\to t_1} Y'(t) = 0 \quad (1)$$

From the results received we can come to a conclusion that Y(t) at $t\to t_0$ is concave and at $t\to t_1$ is a convex function. Therefore, there is a flex point t_{flex}, where $Y''(t_{flex}) = 0$ or its value does not exist. An equation of a logistic function Y(t) can be determined from the very beginning using an exponent equation. An elementary differential equation of an exponential function looks the following way:

$$\dot{Y}(t) = k \cdot Y(t) \quad (2)$$

where k is the growth index. This equation determines the meaning of the speed of innovation diffusion.

$$\frac{dY}{dt} = k \cdot Y \quad \text{or} \quad \frac{dY}{Y} = k \cdot dt \quad (3)$$

Not only time can be chosen as parameter t. In the general case this parameter records some resource outlays for production of a certain volume of effect Y(t). The integration gives the following result:

$$\ln Y = \int_{t0}^{t1} k \cdot dt + Const \quad (4)$$

$$\ln Y = k \cdot t + Const \quad (5)$$

$$Y = A \cdot e^{kt}, \quad \text{where} \quad \ln A = Const \quad (6)$$

The growth index is a variable value. Gradually, as the market saturates with economic welfare Y and the competition on the used resources increases (t), index k gets reduced:

$$\dot{Y} = k(Y) \cdot Y \quad (7)$$

The differential equation of a logistic curve is different from the exponential one by an additional component ($-b \cdot Y^2$), through which the modelling of "dissipation" of the innovative process takes place with the possible stabilization after the period of exponential growth. The required functional dependence, for example, can be represented the following way:

$$k(Y) = a - bY \quad (8)$$

$$\dot{Y} = b \cdot Y \left(\frac{a}{b} - Y \right) = aY - bY^2 \quad (9)$$

The top and the bottom bounds of the logistic function are not constant values, they also depend on the time. The variability of limiting values can distort the trajectory of the evolution of the innovative process. Therefore, to determine the degree of saturation of the need, these variables can be expressed in a relative format (unit fractions) [4]. This way, the dependence of extreme values from the time parameter is levelled off. In a general case, it is possible to allow the existence of the minimum limit g of the logistic function different from zero. The value of the maximum limit is equal to $\left(\frac{a}{b} + g \right)$. Then, having integrated the expression:

$$\dot{Y} = b \cdot (Y - g) \cdot \left(\frac{a}{b} - (Y - g) \right) \quad (10)$$

We get

$$-\frac{1}{a} \ln \frac{(1 - \frac{b}{a}(Y-g))}{b(Y-g)} = t + Const \quad 11)$$

$$Y = \frac{\left[\frac{a}{b} \right]}{(1 + A \cdot e^{-ta})} + g, \text{where} A = a \cdot e^{-C \cdot a}$$

where C = Const. (12)

As a result, we have received a model of a logistic function Y(t), the graphs of which at different values of the parameter A (A1<A2<A3) are shown on Fig. 1. It is indicative that in accordance with the criterion of effectiveness it is possible to separate the logistic curve into three segments:

Low resistance of the external environment when the increasing return effect is observed and $\frac{\Delta Y}{\Delta t} < 1$.

The growth of resistance of the external environment when $\frac{\Delta Y}{\Delta t} > 1$.

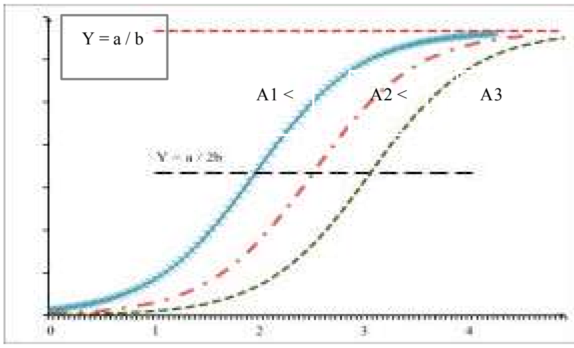

Fig. 1: The comparison of intensiveness of the development of innovative processes

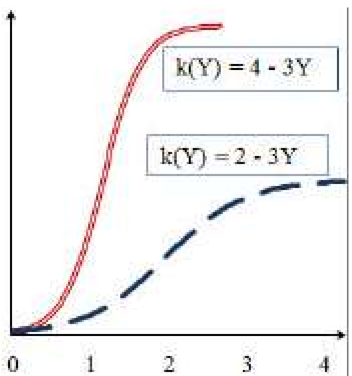

Fig. 2: The comparison of saturation limits of innovative processes

Strong resistance of the external environment when the decreasing return is observed and when there is market saturation at $\frac{\Delta Y}{\Delta t} < 1$.

The second segment represents the largest interest from the position of the intensiveness of development of the innovative cycle. The value of the effect of this segment determines the degree of competitive ability and the internal potential of the chosen innovation. Parameter A characterizes the speed of access of the effective segment of the innovative cycle. The higher is the A value, the slower the innovation accesses the "effective" area (Fig. 1).

The management of an innovative process in the first segment is directed towards the reduction of its duration. If the innovative process is coming closer to the third segment, then the management should be directed towards searching for new substituting technologies. Comparing the elements of curves, describing different innovative cycles we could match the intensiveness of their development. This matching has a practical meaning because the pre-requisites for the justified acceptance of timely managerial decisions

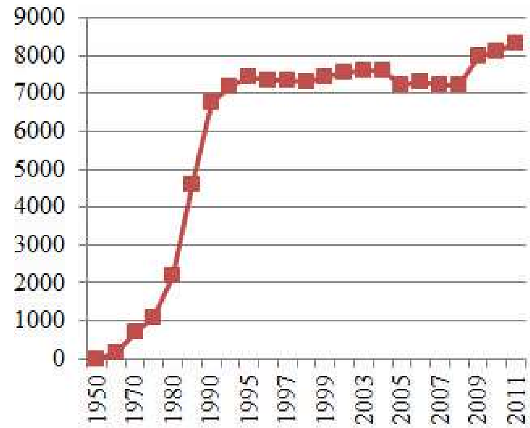

Fig. 3: The number of TV stations [5, 6]

and the evaluation of their economic effectiveness are formed.

Parameters a and b characterizing the intensiveness of development of innovative processes in time and determining the dynamics of the value of the growth coefficient impact Y growth rates. The higher a / b, the higher the rate of achieving the limit of saturation (Fig. 2). The logistic trajectory of dynamics of the innovative cycle is confirmed by numerous statistical data. Thus, Fig. 3 shows a logistic dynamics of the number of TV stations in one of the most innovative and dynamically developing sectors-public use communications and telecommunications.

In a relative format, statistical observations can be shown by logistic curves describing trajectories of innovative cycles of different generations. Due to the growth of intensiveness of innovations of the new generation and speeding up the change of technologies, the duration of an effective segment of a logistic curve becomes shorter.

The history of using obsolete technology (resource) is not finished with its substitution by the new one. The stage of gradual refusal of using it approaches when the economy continues to exploit the so-called "residual resource" of the old technology.

In a number of cases, using the residual resource is quite effective. Therefore, it is possible to consider forecasting the residual resource of a specific technology as a certain state of process management of its final use. Based on the practically horizontal type of graphs (from 2000), it is possible to state on the non-zero level that though the volume of using the data of primary energy resources is not significant, it is quite stable. This type of evolution trajectory of innovative processes is also seen on communications.

A certain growth in parcels from 2004 is probably seen due to the development of Internet sales and the need to deliver goods.

CONCLUSION

The following statistical observations allow us making a conclusion on the stability of extreme states of substitutable technologies (resources) and, therefore, the need to take them into consideration when forecasting the innovative cycle in a more detailed way. From the position of rational economy and careful attitude to resources, production capacities and modelling of innovative processes, the descending area of the curve can be characterized as a reversion of the innovative cycle. Graphically, the achievement of "bottom" extreme states is described by a descending logistic curve when the exponential fall is ended with the stabilization at a certain level that is close to the zero value. Formally, it is a change of the sign of an argument of the logistic function Y(t).

According to our opinion, the suggested analytical foundations of modelling the dynamics of the innovative cycle are an operationally compact and, at the same time, a conceptually substantial method of explanation of the evolution and forecasting of innovative cycles. The logistic model developed reflects the general economic cyclic pattern that the development of any innovative process complies to.

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