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ИЗВЕСТИЯ АКАДЕМИИ НАУК ЭСТОНСКОЙ ССР. ТОМ 20
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SOME METHODOLOGICAL PROBLEMS OF FORECASTING

The sphere of human activities, where the need for predictions is acknowledged, seems to expand at an accelerating pace. The interactions between the different fields of activities — social, economic, scientific and technological — and the advancements in communication systems are factors permanently complicating the task of the predictor.

In an interconnected world naive methods of forecasting which split related phenomena into autonomous processes and extrapolate their run are apt to become all the less valid.

As social processes are directed by the changing will of various individuals, the trends of their development are accordingly less stable than those in nature. Hence, there is a growing need to take into account more interactions and sources of the instability.

In the following treatment we will concentrate on the complications arising from the two-sided interrelations between predictions and reality. In attacking our problem we make use of the term "reflexivity" approximately in the sense given to it in [1]. When regarding conditions under which predictability is achievable despite reflexive effects of the prediction, we follow up the line taken in [2, 3].

From such general treatment we turn to ramifications in more restricted areas, such as economic, scientific and technological development. We try to interpret the general conclusions in a more specified framework of those areas and search for special problems potentially conceivable in them.

1. Reflexivity: conditions of occurrence

By reflexivity of prediction we mean the impact of this particular prediction on shaping reality. Such a phenomenon becomes evident only in a certain class of events. This class of events includes those occurring in social systems, or, more exactly, those concerning the behaviour of human individuals or events related to their behaviour. In predicting natural phenomena not depending on human behaviour we cannot expect any reflexivity. The widening of human influence on nature means, of course, a widening of this potential sphere of reflexive predictions.

To comprehend our problem more compactly, let's try to represent the case of reflexivity by means of formal logic. To achieve this effect we use

$$p \rightarrow q$$

as meaning "from p we can predict q". Let p denote a certain set of laws in conjunction with initial conditions. Let's assume that predicting q implies changes (denoted by v) in the behaviour of the individuals concerned:

$$q \rightarrow v$$

If changes v in the behaviour of individuals represent a change in initial conditions then we can say that p is substituted by some p'. In case differences between p and p' are negligible, and both

$$p \rightarrow q$$

and

$$p' \rightarrow q$$

are valid, we can say that reflexivity does not take place.

But if

$$p' \rightarrow q', \text{ and}$$

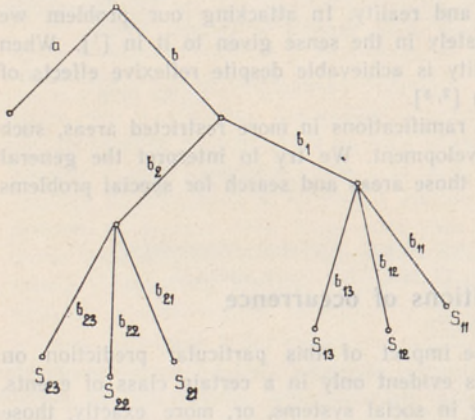
$$q \neq q'$$

then the prediction has entered the situation as a new dynamic factor, and its impact on the run of the process cannot be disregarded.

For connecting the behaviour of several individuals with causal chains, certain requirements for communication must be satisfied [4]. Information about the decisions and actions of any individual must be communicated to others. Similarly, the prediction cannot be turned into a stimulus unless there is sufficient communication. Whatever the prediction, it will not play the role of a causal factor if it is known only to the predictor (except when changes in the behaviour of the predictor are adequate for influencing the situation).

Besides dissemination, there is another mediating factor between prediction as a stimulus and shape of reality — that is, the formation of beliefs on the part of various individuals in a social situation. It's quite natural to assume that such beliefs may appear in different modified forms and that certain additional factors may influence them.

Let's regard a hypothetic scheme-classification of the influence of beliefs on the behaviour of an individual i:



In this scheme, the states of beliefs are denoted as follows:

a — non-belief;
b — belief;
b_1 — conditional belief;
b_2 — unconditional belief.

The individual i may or may not believe the fulfilment of the prediction. In case of non-belief, further classification is excluded and a certain behavioural pattern follows. In case of belief, the classification chain continues. Belief of an individual i in the fulfilment of the prediction P may be conditional or unconditional. Conditional belief means that the individual i regards the fulfilment of the prediction possible under additional conditions. But at the same time he isn't sure of the fulfilment of those conditions. Unconditional belief means that the individual i regards the fulfilment of the prediction P inevitable.

At the next stage, the preferences of an individual play their role in determining behaviour. That means: it is relevant whether the individual i prefers the fulfilment of the prediction to its non-fulfilment. In case of conditional belief, the individual's preferences play a more important role than in case of unconditional belief.

Preferences of the individual i concerning the fulfilment of the prediction P may be denoted as follows:

b_{11}, b_{21} — $P \underset{i}{\succ} \overline{P}$, i. e. individual i prefers the fulfilment of the prediction P to its non-fulfilment;

b_{12}, b_{22} — $P \underset{i}{\sim} \overline{P}$, i. e. the individual i is indifferent to the fulfilment or non-fulfilment of the prediction P;

b_{13}, b_{23} — $P \underset{i}{\prec} \overline{P}$, i.e. the individual i prefers the non-fulfilment of the prediction P to its fulfilment.

Possible changes in the behaviour of the individual i resulting from the influence of prediction P can be specified in a scheme. They may be denoted as follows:

s_0 — no changes in behaviour, passivity;

s_{11} — endeavour to create necessary (and sufficient) conditions for the fulfilment of the prediction P;

s_{12} — partial preliminary adaptation to the prediction P, that means, the predicted state of affairs is regarded as one from the set of possible states and the individual is preparing to achieve homeostatic equilibrium in case of its occurrence;

s_{13} — endeavour to frustrate the fulfilment of the prediction P, that means, an endeavour to prevent the creation of necessary (sufficient) conditions for the fulfilment of the prediction P;

s_{21} — preliminary adaptation to the prediction P, accompanied by emphasizing the inevitable fulfilment of the prediction P (or importance of the predicted event). The generated pattern of behaviour is similar to behaviour in case of religious belief;

s_{22}, s_{23} — preliminary adaptation to the prediction P. In its strongest form (only s_{23}) it may be adaptation to an inevitable disaster.

It can be noticed that a preliminary adaptation to the prediction by individuals is not always an act neutral to the fulfilment of the prediction. Adaptation can make a contribution to the frustration (especially easily conceivable in predicting prices) or to the fulfilment of the prediction.

For the relevance of the scheme presented one more general condition must be satisfied. For generating behaviour patterns specified above, especially those of active exertion of influence or adaptation, an individual i mustn't be indifferent to any of the two possible future events. Or, more exactly: among possible (conceivable) future events there must be at least one event, the occurrence of which is, from the point of view of the individual i, preferable to the occurrence of other events.* If this condition is not satisfied, then it is not logical even to expect a preliminary adaptation by the individual. Our scheme has some relevance in case of partial indifference (for some future events the individual i has a preference preordering). In case of full indifference (between any of the two future events the individual i can't put the sign $\underset{i}{\succ}$), passivity becomes a dominant behaviour pattern and beliefs don't play any role. In such conditions our classification becomes meaningless.

Let's assume that a set of individuals, with whose behaviour or actions the predicted event is connected, consists of n individuals. Then reflexivity of the prediction depends on the changes in the behavioural patterns of those individuals as a result of the dissemination of this prediction and belief formation (changes in the distribution of behavioural patterns between possible alternatives). In most cases it is reasonable to assume that there exists a certain critical quantity of individuals m ($1 \leqslant m \leqslant n$), changes in whose behavioural patterns (reactions to the prediction) will cause reflexivity.

2. Self-fulfilling and self-frustrating predictions

Reflexive predictions have been classified into self-fulfilling and self-frustrating ones [1]. Such a classification does not include cases, in which the actual state declines from the predicted one, but the declination is of a different character than that occur-

* This idea is a modified version of J. J. Rousseau's: "What yoke can be put on people who need nothing?" [5].

ring in the "prediction-free" condition. Such a classification may be sufficient, of course, when a set of alternatives can be represented in some metric space. Then predictions can be classified into self-fulfilling and self-frustrating ones according to the increase or decrease of the distance between the actual and predicted state as a result of the dissemination of the prediction.

In case of reflexivity (or expected reflexivity) attempts can be made to avoid it. One strategy for avoiding reflexivity follows from the treatment given above. It consists in preventing the dissemination of the prediction to individuals (or at least to a certain critical quantity of them) whose actions can influence the truth-value of the prediction. Such a strategy can be taken into consideration if a self-frustrating operation of the prediction is expected.

Another possible strategy is to bring the expected results of the dissemination of the prediction to the attention of interested individuals. It means that the prediction refers to the effects of an earlier prediction. In such a way an infinite sequence of predictions can be formed. A predictor may attempt to restrict the dissemination of information in such a way as to create suitable informational premises for the fulfilment of the first prediction. But in certain contexts the setting up of such a target may prove to be too narrow-minded.

In forming the sequences of predictions, an additional problem arises, that of discerning between subsequent predictions. In other words, it can be characterized as a problem of the partition of assertions about the future into ordered (numbered) predictions.

But, fortunately enough, the problem of reflexive predictions is amenable to mathematical treatment. Such a treatment helps to eliminate problems connected with the formation of a sequence of predictions and its convergence.

3. Fixed point and predictability

The possibility of the formation of an infinite sequence of predictions may lead to the conclusion that in circumstances of reflexivity the fulfilment of predictions is impossible.

But it has been demonstrated that despite reflexivity it is possible, under certain conditions, to produce predictions that will prove correct [2, 3, 6]. The possibility to give correct public predictions in a situation where individuals react to predictions has been proved by using Brouwer's Fixed Point Theorem.*

Let S_T be a set of logically conceivable predictions at the moment T. Let's assume that this set is a non-empty compact and convex subset of E^m.

Let the moment of prediction T be separated from the moment of occurrence $T+t$ by the interval $[T, T+t]$. Let's denote the set of logically conceivable states of reality in a prediction-free condition by S_{T+t}. Let the elements of the sets be denoted by $x_T \in S_T$ and $x_{T+t} \in S_{T+t}$.

Let there be in the set $S_T \times S_{T+t}$ a certain set of elements (x_T, x_{T+t}) for which $x_{T+t} = f(x_T)$ is a continuous mapping. With every element x_T from the given set S_T a non-empty subset X_{T+t} of the set S_{T+t} is defined. The graph of the reaction function f is a subset $\{(x_T, x_{T+t}) \in S_T \times S_{T+t} \mid x_{T+t} = f(x_T)\}$ of the set $S_T \times S_{T+t}$.

Let's assume now that the sets S_T and S_{T+t} are equal. Let's denote $S_T = S_{T+t} = S$. This assumption means that it is possible to predict correctly the interval to which the state of reality will belong.

If such assumptions hold, then there exists a fixed point of the continuous mapping f from the set S to the set S (or from the set S_T to the set S_{T+t}). It means that in case of the existence of the function f, it is possible to give a prediction that will prove true.

* Brouwer's Fixed Point Theorem: Any continuous mapping of a closed convex bounded subset of E^m into itself has at least one fixed point. That is, there is a point x such that $Tx = x$ [7, p. 125].

It is interesting to note that continuity of the reaction function f and boundedness of the set of states are sufficient but not necessary conditions. It means that a fixed point may exist even if these conditions are not fulfilled. In such a case, the existence of a fixed point is not guaranteed.

If the reaction function is known, then Brouwer's Theorem enables to abandon the study of a convergence of a sequence of predictions and give a valid prediction at the first try.

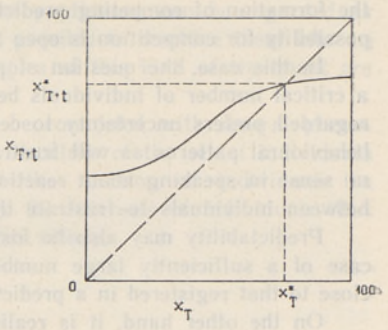
The possibility of the application of this theorem has been demonstrated on examples [2, 3] from economic and social fields.

Let's regard an example of the application of Brouwer's theorem. A predictable phenomenon can be characterized by a number belonging to the closed interval [0, 100]. The predicted state $x_T \in [0, 100]$ and actual state $x_{T+t} \in [0, 100]$. The actual state is a continuous function of the predicted state:

$$x_{T+t} = f(x_T).$$

This situation can be illustrated by a figure. On the horizontal axis, a predicted state x_T is represented as belonging to the interval [0, 100]. The actual state x_{T+t} is represented on the vertical axis and belongs to the same interval.

The fixed point is a point of intersection between the graph of the function f and the dotted diagonal. For this point $x^*_{T+t} = x^*_T$. It means that if the predictor predicts x^*_T, then (and then only) his prediction will be confirmed.



H. Simon has given this example a concrete meaning in predicting voters' behaviour [2]. He assumes that the behaviour of voters is a function of their expectations concerning the results of the elections. The published predicitons are assumed to influence those expectations, and hence the voting behaviour of a certain number of voters.

The prediction of the percentage of voters who will vote for the candidate K_1 in case of a competition between two candidates is regarded.

By y is denoted the percentage of voters who would have voted for K_1 in a prediction-free situation; x_{T+t} is the percentage of voters who in fact voted for the candidate K_1 after the publication of the prediction, and x_T is the percentage who, according to the prediction, intended to vote for K_1.

x_{T+t} is presented as a function of y and x_T:

$$x_{T+t} = f(y, x_T).$$

Under certain conditions, y may be regarded as a given quantity. For the purpose of analysis it is now possible to represent x_{T+t} as a function of x_T alone. It means that we have a case illustrated in the above figure, and sufficient conditions for the existence of a fixed point established by Brouwer's Theorem are satisfied.

This example is of interest only from the methodological point of view. As problems of manipulation with voters' behaviour do not have any bearing in conditions of socialism, we are not interested in them.

4. Problems following from the existence of a fixed point

A solution of the problem of predictability in case of a reflexive operation of predictions raises several new problems. Let's consider some of them.

A. A case of several fixed points

If the conditions specified by Brouwer's Fixed Point Theorem hold, then the existence of at least one fixed point is guaranteed. But the existence of several fixed points is possible as well. In the latter case, two possibilities must be discerned:

a) the predictor (or society) does not prefer any fixed point to other fixed points;

b) a certain fixed point (or several of them) is (are) preferable, from the point of view of the predictor (or society), to other fixed points.

In the first case, choice may take place at random. But reliability of data concerning the shape of the reaction function at different intervals may be taken into account.

In the second case, it is possible to select the preferable fixed point in accordance with certain criteria. The selection of this fixed point contributes to the fulfilment of the prediction.

B. Competition between predictions and certainty of development

By locating a prediction at a fixed point and publicizing it, it seems to be possible to achieve, to some extent, certainty of development. This certainty can be shaken by the formation of competing predictions and their dissemination. An especially interesting possibility for competition is open if several fixed points exist.

In this case, the question of preference between certainty and uncertainty arises. If a critical number of individuals belonging to a set of individuals influencing the process regarded prefers uncertainty to certainty, then they can agree on such a distribution of behavioural patterns as will frustrate a given prediction. Under those conditions there is no sense in speaking about reaction function and its shape. If there exists an agreement between individuals to frustrate the prediction, then predictability is lost.

Predictability may also be lost if several competing predictions are disseminated. In case of a sufficiently large number of competing predictions, the actual state may be close to that registered in a prediction-free condition.

On the other hand, it is realistic to assume that certain situations exist, in which all individuals are interested in reducing uncertainty. Sometimes even no formal agreement is needed to achieve this end. Common (or close) interests of individuals may be sufficient for creating general support for a certain prediction, avoiding at the same time the establishment of competing predictions or their dissemination. As a result of such behaviour, the probability of the fulfilment of this unique prediction may be increased.

If we regard as valid the position taken by J. K. Galbraith in his work [8], then it is reasonable to expect that, in predicting economic conjuncture in developed capitalist countries, a situation analogical to the one described above may occur. Galbraith asserts that the endeavour to reduce uncertainty is characteristic of corporations in developed capitalist countries. In such conditions, one may expect that the corporations will, to some extent, support the prediction of economic conjuncture given by a governmental forecasting centre. A policy reducing uncertainty is adopted by individuals (corporations) mainly for fear that they may suffer losses if they fail to make investments required for the production of commodities for which there is or might be a demand. The stakes under risk increase permanently because the contemporary scientific and technological development is connected with increasing investments. The possibility to increase a certainty of conjuncture with the help of predictions may seem to be tempting from the point of view of the corporations, and it is apt to be used.

But the gains from reducing uncertainty are not so clear in other areas as in case of economic development. Scientific and technological development cannot be treated with a simple formula of reducing uncertainty. Here an optimal level of certainty-uncertainty exists for every moment. An analogical idea has been expressed by F. Khilyuk and V. Lisichkin, whose point of view is that predictions of scientific and technological development, being valuable indicators in allocating investments and other resources, should not

impede unforeseeable scientific inventions [9]. To find and develop a larger number of non-conforming scientists is regarded by W. Gilman to be an important task for thus the abilities of the whole scientific community will be better expressed [10]. Such non-conforming personalities may counterbalance the determining influence (or rigidity) created by predictions and plans.

In forecasting scientific and technological development, predictability and the existence of a fixed point acquire a meaning different than in predicting economic development. In the former case, more thorough investigations are needed for forming preferences between the fixed point and the other points of the graph of the reaction function.

As distinct from the trends of economic development, different trends of scientific research needn't exclude each other. Two economic conjunctures cannot be realized at the same time, but several scientific inventions or trends of scientific development can (provided that limitations of resources do not become an impeding factor). Such features and also difficulties of quantitative measurement complicate the task of the representation of alternatives of scientific development as a subset of the Euclidean space. This, of course, does not exclude reflexivity and methodological problems generated by it. In such a case, it is more difficult to demonstrate the validity of formal schemes.

A competition between predictions of scientific development is less distinctly observable than between economic predictions. Different predictions can be regarded as each other's complements rather than competitors. It is possible to combine them into an integrated system of predictions (the best-known examples of this kind of treatment are the method "Delphi" and the system PATTERN).

The problem of the reflexivity of predictions can be connected with several phenomena and factors. Among them are the organisational structure of the set of individuals under consideration, additional possibilities to restrict the reaction of individuals to predictions, the problems of matching the prediction to the interests of individuals. But those questions will remain outside the framework of this article.

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PROGNOSTIKA METODOLOOGILISI PROBLEEME

Resümee

Artiklis käsitletakse prognooside ja tegelikkuse vastastikuseid seoseid. Nende seoste olemasolu võib takistada ekstrapoleerimismeetodi rakendamist prognoosimiseks. Kasutatakse mõistet *refleksiivsus,* mille all mõistetakse prognoosi mõju tegelikkuse kujunemisele.

Selgitatakse refleksiivsuseks vajalikke tingimusi ja näidatakse, et refleksiivsuse korral on võimalik ennustatavust selgitada Brouweri püsipunktiteoreemi abil.

Käsitletakse püsipunkti olemasolust tulenevaid probleeme seoses prognoosimisega. Näidatakse, et teaduslik-tehniliste ja majanduslike prognooside puhul tulenevad püsipunkti olemasolust mõnevõrra erinevad probleemid ja järeldused.

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НЕКОТОРЫЕ МЕТОДОЛОГИЧЕСКИЕ ПРОБЛЕМЫ ПРОГНОСТИКИ

Резюме

В статье рассматриваются взаимосвязи между прогнозами и действительностью. Существование двусторонних взаимосвязей может служить препятствием при применении методов экстраполяции для прогнозирования. Использовано понятие рефлексивности. Под этим подразумевается воздействие прогноза на формирование действительности.

Исследуются условия, необходимые для рефлексивности. Показано, что при рефлексивности вопрос прогнозируемости решается с помощью теоремы Брауэра о неподвижной точке.

Рассматриваются проблемы, вытекающие из существования неподвижной точки при прогнозировании. Показано, что при научно-технических и экономических прогнозах из наличия неподвижной точки вытекают проблемы и следствия, в какой-то мере отличающиеся друг от друга.

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