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ARAŞTIRMA MAKALESİ / **RESEARCH ARTICLE**

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THEORETICAL GAME MODELS FOR WORKING OUT AND ANALYZING MECHANISMS FOR KIOTO PROTOCOL REALIZATION

ABSTRACT

Game models are constructed for the production-ecological interaction of main macro agents of geopolitical process of social-economical planet development. Strong equilibriums is considered game models are determined. Principles of "just" determination of quotas on hotbed gases, based on planet interest and equilibrium conditions are developed.

Keywords: Global climate, Game models, Strong equilibriums

KYOTO PROTOKOLÜNÜ GERÇEKLEŞTİRMEDE MEKANİZMALARIN ÇALIŞMA VE ANALİZİ İÇİN TEORİK OYUN MODELLERİ

ÖZ

Sosyo-ekonomik küresel gelişimin temel makro faktörlerinin üretim-ekolojik etkileşimi için oyun modelleri kurulur. Oyun modellerinin incelediği güçlü denge durumları belirlenir. Dünya üzerinde çıkar ve denge durumlarını temel alan sera gazı kotalarının "tam yerinde" belirleme ilkeleri geliştirilmiştir.

Anahtar Kelimler: Küresel iklim, Oyun modelleri, Güçlü denge durumları

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1. INTRODUCTION

Global climate change became scientific and political problem at the same time- one of the biggest scientific riddles of the century. The majority of the specialists thinks that the determining role in the global climate change process takes the increase of the greenhouse effect caused by the anthropogenic factors. See for example, Leonardo Massai (2010) and KOH Kheng-Lian et al. (2009).

The Kioto Protocol is the international document, accepted in Kioto(Japan) in December, 1997 further to the Framework Convention of the UNO about the climate change (FCCC). The period of the protocol signing began on the 16th of March in 1998 and ended on the 15th of March in 1999.

The protocol became effective on the 16th of February in 2005, after the official document transfer about the ratification from Russia to the Secretariat of FCCC in November, 18, 2004.

At the present time the convention sides are more than 190 countries- including Russia, all industrially developed countries and the countries of the former Soviet Union. The USA is curious the exclusion from this list.

The convention is going to integrate the efforts for prevention of dangerous climate changes and achieve the stabilization of greenhouse gases concentration in the atmosphere at the relatively safe level of 1990.

The countries of the protocol defined the quantitative obligations for limiting or cutting the emissions for the period from the 1st of January 2008 till the 31 December 2012. The aim of limiting is to reduce the total average level of emissions of 6 kinds of gases by 5,2% in comparison with the level of 1990.

The industrial countries took the main obligations:

EU must cut the emissions by 8%;

Japan and Canada - by 6%;

Countries of Eastern Europe and Baltic – at the average by 8%.

Developing countries, including China and India didn't take any obligations.

2. BASIC PROVISIONS of KIOTO PROTOCOL

Now the questions of conceptual character, connected with the development and taking objective nonpolitical criteria of defining the quotas for greenhouse gases emissions and reasonable quota trading rules are actively discussed.

The present work offers two alternative mechanisms for defining such quotas: the mechanism, based on the search of strong equilibrium in the game, describing ecological interaction of the world countries and the mechanism, based on defining quotas, proceeding from the optimization of ecological economic interests of planet as a whole.

So the basic problems are:

1. Defining permissible volume of greenhouse gases emissions in 2008-2012 for all the industrially-developed member-countries , participating in this agreement

2. Developing the mechanisms of updating the quotas for certain countries-"mechanism of flexibility" (international quota trading, realization of new co-projects and technology, providing the emissions cutting and etc.)

3. Developing of the control mechanisms over the emissions level (necessity of creating national systems of man-made emissions valuation and their absorption, monitoring the emissions and flows).

There are 6 kinds of greenhouse gases, considered at the estimated factors of reducing or cutting emissions in the list of greenhouse gases:

CO_2- carbon dioxide,
CH_4-methane,
N_2O-nitrous oxide,
And also 3 groups of long-life industrial gases:
HFC_S - hydroflourhydrocarbon,
PFC_S - perflourhydrocarbon,
SF_6

So the impact of CO_2 is 80%, CH_4-15%.

Total impact of these 6 greenhouse gases are estimated by the formula of reduction to CO_2:

$$w_i = \sum_{j=1}^{6} \mu_i \cdot w_i^j$$

The potential coefficients of the global warming of greenhouse gas μ_1 are counted in accordance to greenhouse gases effects for hundred time horizon, (actually proceeding from thermal conduction of gases). As everything is reduced to influence equivalent of CO_2 (j=1), $\mu_1 = 1$. For methane (CH_4) is $\mu_2 = 21$, for nitrous oxide (N_2O), $\mu_3 = 310$, etc.

Hotbed gases emissions by more 'smoky' countries and regions, ml. t. per year. (Initial dates) are:

USA	36%
EU	21%
China	18%
Russia	15%
Japan	5%
India	5%

Note, that now China has emissions more than USA.

3 .THEORETICAL GAME MODELS FOR WORKING OUT and ANALYZING MECHANISMS FOR KIOTO PROTOCOL REALIZATION

So the main problems of synthesis of mechanisms of Kioto protocol decision realization in these model are:

1. The estimation of the industrial – economic activity for global ecology.
2. The choice (calculation) of reducing emissions' volume.
3. Argumentation of taken obligations for emissions' reducing.
4. Economic estimation of taken obligations and mechanisms of economic interaction for consideration of:
   - quota trading,
   - Realization of joint projects, improving the ecology of technology.

So the offered models must help to obtain the solution of these problems.

The mathematical models of two types are offered for solving these actual problems.

The first model has common goal (greenhouse gases emissions minimization) and individual functional (effective using of energy resources).

Theoretical game analysis of this model solves political issues. It will permit to make more reasonable the process of dividing countries into two categories:

- Developed countries that take the main financial obligations for the Kioto protocol realization.
- Underdeveloped and developing countries, that need such a financial support.

The second model is geopolitical model of rational use of energy resources including the ecological section.

Analysis of this model will permit to estimate more reasonably emissions cutting parameters, quotas financial valuation and efficiency of joint ecological programs.

Further the description and analysis of the elementary type of this models are considered.

We will consider a single product, single resource model of ***n*** the states, participating in the development and realization of mechanisms, contributing greenhouse gases emissions, connecting with the industrial activities:

x_i - Resource (energy),

$f_i(\alpha_i, x_i)$ -income, for example, Gross National Product (GNP),

α_i - Parameter of economic efficiency of using technology,

$w_i(b_i, x_i)$ - Greenhouse gases emissions,

b_i - Ecological parameter of using technology.

We take a symbol *H* for initial value of parameters:

$$x_i^H, \quad w_i^H = w_i\left(b_i, x_i^H\right),$$

$W^H = \sum_{i=1}^{n} w_i^H$ - Total emissions

In the existing opinion the total volume of greenhouse gases emissions - W^H exceeds acceptable limits. So we need to choose the acceptable limit $W^K < W^H$.

And it is necessary to "factorize" the difference to states

$$\Delta W = W^H - W^K = \sum_{i=1}^{n} \Delta w_i \ ,$$

So «justly» to find limits of emissions cutting volume Δw_i .

So, on the one hand every government is interested in increase of individual criteria f_i (steady economic growth), on the other hand, aims at achieving to the greatest possible reduction of total amount of emission of hotbed gases by all states ΔW .

So as a comparison we take criteria of the states as:

$$M_i = \min\left[\Delta W, \alpha_i f_i\right] \to \max \tag{1}$$

where the $\alpha_i \geq 0$ parameter defines degree of "altruism" of a state ***i***.

So, we have received theoretical game model of interaction of the ***n*** subjects with the goal functions (1) and restrictions on strategies and Δw_i :

$$0 \leq x_i \leq x_i^+, \tag{2}$$

$$0 \leq w_i \leq w_i^H - \Delta w_i, \tag{3}$$

where x_i^+ - restriction, for example, on presence of a resource or capacities.

4.BASIC RESULT

On the functions f_i and w_i we will impose natural conditions of continuous and monotonous increase on x_i

.

Let's define sets $N = \{1,2,...,n\}$ and

$$N_1 \subset N, \quad N_2 \subset N, \quad N_1 \cup N_2 = N, \quad N_1 \cap N_2 = \varnothing$$

In the formulated conditions the theorem is fair:

Theorem: The necessary and sufficient condition of the fact that $x_i^0, \Delta w_i^0 \quad i = 1,...,n$ is the strong equilibrium in the game (1)-(3) is in existence of N_1 and N_2 so that:

$$1) \qquad \sum_{i=1}^{n} \Delta w_i^0 = \Delta W^0 = \alpha_i \cdot f_i\left(a_i, x_i^0\right), \quad \Delta w_i^0 \geq 0, \quad i \in N_1$$

$$2) \qquad \Delta W^0 > \alpha_i \cdot f_i\left(a_i, x_i^0\right), \quad \Delta w_i^0 = 0, \quad i \in N_2$$

Owing to properties of a situation of strong equilibrium it is not favorable to deviate from the received decision for anybody of players separately (Nash equilibrium), any coalition, including the coalition of all the players simultaneously (an optimality on Pareto).

Players from set N_1 - the states with strong economy, non-polluting technologies are strongly interested in a solution of the global warming problem (altruists).

Players from set N_2 - the states with poorly effective economy, "dirty" technologies and selfishly approaching to the solution of the world-wide problems.

By the way, investigating a problem (1) - (3), by data from the accepted obligations Δw_i^K and Δx_i^K it is possible to calculate indicators of altruism (egoism) of the states:

$$\alpha_i = \frac{\Delta W^K}{a_i\left(x_i^+ - \frac{\Delta w_i^K}{b_i}\right)}, \quad if \ \Delta w_i^K > 0,$$

$$0 \le \alpha_i \le \frac{\Delta w_i^K}{a_i x_i^+}, \quad if \ \Delta w_i^K = 0.$$

Especially we underline absolutely qualitative comparability of the received decision with the decisions of the Kioto Protocol: splitting of the countries into two groups with the different degree of obligations.

5. OPTIMIZATION AGGREGATED MODEL of THE ANALYSIS of MECHANISMS REALIZATION of THE KIOTO PROTOCOL

Further we stop on a problem of using the models, promoting working out and realization of mechanisms of cooperative actions. We consider a task:

Total GNP

$$F = \sum_{i=1}^{n} f_i \Rightarrow \max \tag{4}$$

At the local restrictions (2), (3):
and global restriction

$$W = \sum_{i=1}^{n} w_i \le W^k \tag{5}$$

From the decision of local (1) - (3), and global (2), (4), (5) optimizing models we can define the prices for quotas of greenhouse gases emissions.

Having dependence of factors a_i and b_i from the investments it is possible to estimate advantage of participation in joint projects.

6. LINEAR GAME MODEL of ECOLOGICAL INTERACTION of THE STATES

For the purpose of a concrete definition and development of results the linear variant of the model is investigated. In this case dependences of gross national product and emissions were considered as the linear functions.

Let's write out conditions for our special case. As the “poor” countries aren't going to reduce emissions ($\Delta w_i(x_i^0) = 0$), so:

$$\Delta W(x_i^0) = \sum_{i \in N_1} b_i \cdot (x_i^H - x_i^0)$$

$$\Delta W(x_i^0) = \alpha_i \cdot a_i \cdot x_i^0, i \in N_1$$

$$\Delta W(x_i^0) = \alpha_i \cdot a_i \cdot x_i^H, i \in N_2$$

These correlations provide the situation of the strong equilibrium.

Let $N_1 = \{1,...,k\}, N_2 = \{k+1,...,n\}$, then first two conditions give system from *k+1* the equations respective to *k+1* variables x_i^0, $i = 1,...,k$ and $\Delta W(x_i^0)$:

Finelly we will receive:

$$\Delta W(x_i^0) = \frac{\sum_{i \in N_1} b_i x_i^H}{1 + \sum_{i \in N_1} \frac{b_i}{\alpha_i \cdot a_i}}$$

$$x_i^0 = \frac{\sum_{i \in N_1} b_i x_i^H}{\alpha_i a_i (1 + \sum_{i \in N_1} \frac{b_i}{\alpha_i \cdot a_i})}$$

It is necessary to divide the countries on "rich" and "poor".

It is obviously, that the member of such variants is equal to 2^n

But if we will order the countries so that:

$$\alpha_1 a_1 x_1^H \geq \alpha_2 a_2 x_2^H \geq \cdots \geq \alpha_n a_n x_n^H,$$

then the number of variants (hypotheses) remains no more, than $n << 2^n$.

This follows from the next:

1. $\Delta w_k = 0 \rightarrow \Delta w_i = 0, i = k+1, \ldots, n$

2. $\Delta w_k = 0 \rightarrow \Delta w_i = 0, i = k+1, \ldots, n$

7. THE RESULTS of CALCULATIONS

For calculations the next algorithm was used:

STEP 0: Let's enter "counter" $m : 0 \le m \le n$, auxiliary variables $S(m)$ and $T(m)$ so, that $S(0) = 0$ and $T(0) = 0$.

STEP m: to count:

$$S(m) = S(m-1) + \frac{b_m}{\alpha_m a_m}$$

$$T(m) = T(m-1) + b_m x_m^H$$

Then to calculate with the formula

$$\Delta W(m) = \frac{T(m)}{1 + S(m)}$$

Further we check the performance of inequalities:

$$\Delta W(m) < \alpha_{m+1} a_{m+1} x_{m+1}^H$$
$$m < n$$

If both inequalities are carried out, so to pass to the STEP m+1, if at least one of these inequalities isn't carried out, then algorithm will be finished.

And

$$x_i = \frac{\Delta W(m)}{\alpha_j a_j}, \quad j \le m, \quad x_j = x_j^{\mathrm{H}}, \quad m \le j \le n$$

8. THERE ARE THE POLITICAL and ECONOMIC VARIANTS:

Table 1. Political and economic variants

States	ΔW equilibrium th.t. CO_2 - eqv.	ΔW world optimum th.t. CO_2 - eqv.
EU	1 298 703	283 002
Japan	228 304	0
Canada	45 978	0
Turkey	2 858	0
Saudi Arabia	3 549	0
Russia	15 374	70 774
India	12 584	118 765
Rest states	87 537	412 091
Korea Republic	4 121	0
Argentina	2 496	291
Brazil	6 380	544
Mexico	4 134	0
USA	52 384	0
China	36 433	916 633
Australia	2 392	1 126
Indonesia	0	0
South Africa	0	0
Total	1 803 227	1 803 227

The analysis of calculation variants at different values of parameters showed that the Turkey government is able to take obligations under condition of increasing economic efficiency parameter ***a*** and volume of the used energy resources more than 30%. In that case the volume of obligations is approximately equal to 2,5% or 5% with respect to base year.

9. CONCLUSIONS

In this work the possibility in principle of using theoretical game models of a special kind for working out and an estimation of the Kioto protocol mechanisms efficiency is shown.

In the presence of correct estimations of factors a_i and b_i and at a well-founded choice of a kind of functions f_i and w_i the considered models allow to receive the concrete values of optimum quotas.

From these values we can estimate degree of "egoism" of the various states at the established quotas and develope rational procedures of trading quotas.

Deeper qualitative and quantitative analysis of considered mechanisms will demand complication of the resulted models in following directions:

1. The account of development of the described processes in dynamics.

2. The account of possibilities of improvement of technologies (innovation), and also a technological transfer on the stipulated conditions.

3. The account of presence of the uncertain factors carrying as objective (not studied enough and badly predicted processes), and subjective (disability or not desire precisely to estimate processes) character.

For more exact quantitative analysis, at the first stage the information of a following kind is required:

- Correct estimations of labor input, a capital intensity, a material capacity, power consumption and ecological compatibility.
- Correct estimations of innovative potential of the states.
- Correct estimations of human potential and natural resources of the states.
- Well-founded alternative forecasts of climate changes on the planet at the various variants of dynamics of the greenhouse gases emissions in the nearest decades.

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