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ENVIRONMENTAL NEGOTIATION UNDER INFORMATION ASYMMETRY: A LABORATORY EXPERIMENT FOR COALITIONS OF FOUR PARTIES

Negotiation between polluters and authorities under information asymmetry where economic instruments of environmental policies are applied belong to alternative mechanisms for solving pollution reduction problems with a potential to achieve the solutions in a cost-effective way. The paper brings the results of a laboratory testing of the situations where polluters can create coalitions of 4 parties. The experiments concluded that even if the experimented situation created quite a number of combinations, the subjects were able to find satisfactory results. It is promising for continuing experiments with a richer structure of coalitions with multiround negotiations and the introduction of multicriteria evaluation of environmental and other effects.

Keywords: *environment; economic laboratory experiments; polluters; negotiations.*
JEL: Q5, C92, D82.

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ЕКОЛОГІЧНІ ПЕРЕГОВОРИ В УМОВАХ ІНФОРМАЦІЙНОЇ АСИМЕТРІЇ: ЛАБОРАТОРНИЙ ЕКСПЕРИМЕНТ ДЛЯ ЧОТИРЬОХСТОРОННІХ КОАЛІЦІЙ

У статті показано, що переговори між забруднювачами середовища та владою в умовах інформаційної асиметрії та застосування економічних інструментів впливу можуть вважатися альтернативним способом вирішення проблеми зниження промислового навантаження на навколишнє середовище, і завдяки цьому способу є потенціал вирішити дану проблему економічно ефективним шляхом. Представлено результати лабораторного експерименту для гіпотетичних чотирьохсторонніх коаліцій. Наведено низку варіантів рішень, до яких можуть дійти коаліції в результаті переговорів. Даний експеримент планується розвивати далі для більш складних структур коаліцій, декількох раундів переговорів та шляхом введення додаткових критеріїв для оцінювання екологічних та інших ефектів від переговорів.

Ключові слова: *навколишнє середовище; економічний лабораторний експеримент; забруднювачі; переговори.*
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ЭКОЛОГИЧЕСКИЕ ПЕРЕГОВОРЫ В УСЛОВИЯХ ИНФОРМАЦИОННОЙ АСИММЕТРИИ: ЛАБОРАТОРНЫЙ ЭКСПЕРИМЕНТ ДЛЯ ЧЕТЫРЕХСТОРОННИХ КОАЛИЦИЙ

В статье показано, что переговоры между загрязнителями среды и властями в условиях информационной асимметрии и применения экономических инструментов влияния могут считаться альтернативным способом решения проблемы снижения промышленной нагрузки на окружающую среду, и благодаря этому способу есть потенциал решить данную проблему экономически эффективным путём. Представлены результаты лабораторного эксперимента для гипотетических четырехсторонних коалиций.

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Предложен ряд вариантов решений, к которым могут прийти коалиции в результате переговоров. Данный эксперимент планируется развить для более сложных структур коалиций, нескольких раундов переговоров и путём введения дополнительных критериев для оценки экологических и других эффектов от переговоров.
Ключевые слова: *окружающая среда; экономический лабораторный эксперимент; загрязнители; переговоры.*

1. Introduction

Solving environmental problems in a cost-effective way is an important task for environmental economics and policy theory and practice. This paper presents such an approach to achieving environmental policy goals where polluters and authorities negotiate for financial support from a fund, while information asymmetry between authorities and polluters is present. The authority distributes financial resources in a one-round auction. Polluters know their individual abatement costs and try to maximize their surplus, which they can get if they apply for and negotiate higher support from the authority than the minimum they need, so the projects are efficient for them (for more details about understanding the minimum support see Sauer et al., 1998; Sauer et al., 2003).

Compared to the model mentioned above, in the case described in this paper subjects are also given a chance to establish coalitions to achieve goals in environmental protection. After negotiating with coalition partner (s), the subjects apply for financial support to the coalition project (s) together with their individual projects.

The research questions were formulated as follows. Let there be the possibility to create coalitions with up to 4 parties/subjects: (1) to what extent can the negotiated result be close to the computed optimum solution, and (2) how do the coalition subjects distribute the "extra cake" from getting higher support than the minimum?

Economic laboratory experiments were used as the method to answer the research questions. The use of this research methodology has had an increasing tendency in both fundamental and applied studies. Arguments on the pros and cons of the use of economic laboratory experiments are discussed, for instance, in Smith (1976), Davis & Holt (1993), Roth (1995), Levitt & List (2007), and Falk & Heckman (2009).

The paper is structured as follows: The model of combinatorial auctions for coalitions of four subjects is described first. This model served as the theoretical basis for the economic laboratory experiments presented in the second part of the paper.

2. Theoretical model for the experiment – reverse combinatorial auction

The model of combinatorial auction of indivisible items with one buyer (authority) and several sellers (polluters in our case) serves as the theoretical basis in our problem. This type of auction is typical for the supplier selection problem. For more details, see Cramton et al. (2006), de Vries and Vohra (2003), or Pekec and Rothkopf (2003).

In our case, we suppose that 4 potential sellers S_1, S_2, S_3, S_4 offer a set R of items (projects in our case) to one buyer B (authority) (see Figure 1).

A bid made by seller S_h, $h = 1, 2, 3, 4$, is defined as

$$b_h = \{C, c_h(C)\} \qquad (1)$$

where

$C \subseteq R$ is the combination of items,

$c_h(C)$ is the price offered by seller S_h for the combination of items C.

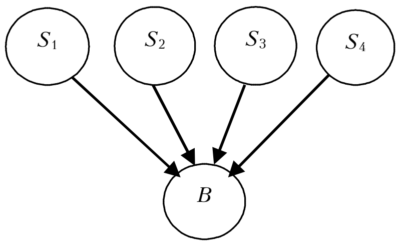

Figure 1. **Reverse auction,** *developed by the authors*

The objective is to minimize the buyer's cost given the bids made by the sellers. Constraints establish that the procurement provides at least a set of all items.

Bivalent variables are introduced for model formulation:

$y_h(C)$ is the bivalent variable specifying whether the combination C is bought from seller $S_h(y_h(C) = 1)$.

The reverse combinatorial auction can be formulated as follows:

$$\sum_{h=1}^{4} \sum_{C \subseteq R} c_h(C) y_h(C) \to \min \tag{2}$$

subject to

$$\sum_{h=1}^{4} \sum_{C \subseteq R} y_h(C) \geq 1, \forall j \in R \tag{3}$$

$$y_h(C) \in \{0,1\},\ \forall C \subseteq R,\ \forall h,\ h = 1,2,\ldots,m. \tag{4}$$

The objective function expresses the cost. The constraints ensure that the procurement provides at least a set of all items. The CRAB (CombinatoRial Auction Body) software system (Fiala et al., 2010) can be used for finding the best solutions and evaluation of project proposals. The CRAB is a non-commercial software system for generating, solving, and testing combinatorial auction problems.

3. Laboratory experiment design

The experiment was designed for the groups of 4 subjects-polluters. 4 groups of 4 (16 subjects) were grouped into cohorts representing polluters in a hypothetical territory. In reality, we can imagine, for instance, there are 16 polluting subjects located in a river basin. The background model consisted of the following data/variables/information:

Pollution reduction (dP)

a) individual projects: $dP(A)$, $dP(B)$, $dP(C)$, $dP(D)$

b) joint (coalition) projects: $dP(A+B)=dP(A)+dP(B)$; $dP(A+C)=dP(A)+dP(C)$; $dP(A+D)=dP(A)+dP(D)$; $dP(B+C)=dP(B)+dP(C)$; $dP(B+D)=dP(B)+dP(D)$; $dP(C+D)=dP(C)+dP(D)$

$dP(A+B+C)=dP(A)+dP(B)+dP(C)$; $dP(A+B+D)=dP(A)+dP(B)+dP(D)$; $dP(A+C+D)=dP(A)+dP(C)+dP(D)$; $dP(B+C+D)=dP(B)+dP(C)+dP(D)$

$dP(A+B+C+D)=dP(A)+dP(B)+dP(C)+dP(D)$

Costs of projects (C)

a) individual projects: $C(A)$, $C(B)$, $C(C)$, $C(D)$

b) joint (coalition) projects: $C(A+B)$; $C(A+C)$; $C(A+D)$; $C(B+C)$; $C(B+D)$; $C(C+D)$

$C(A+B+C)$; $C(A+B+D)$; $C(A+C+D)$; $C(B+C+D)$

$C(A+B+C+D)$

Minimum support (S_{min}) that should be required by the subjects:

a) individual projects: $S_{min}(A)$, $S_{min}(B)$, $S_{min}(C)$, $S_{min}(D)$

b) joint (coalition) projects: $S_{min}(A+B)$; $S_{min}(A+C)$; $S_{min}(A+D)$; $S_{min}(B+C)$; $S_{min}(B+D)$; $S_{min}(C+D)$

$S_{min}(A+B+C)$; $S_{min}(A+B+D)$; $S_{min}(A+C+D)$; $S_{min}(B+C+D)$

$S_{min}(A+B+C+D)$

Required support (Srq) – the subjects-polluters can decide to apply for a support to all of the possible options (combinations) or only to some of them.

The best solutions

The theoretically best solutions were computed by the CRAB system mentioned above.

The first best (optimal) solution:

Coalition structure ($A+B+C; D$), the minimum costs of the optimal solution: 80 + 20 = 100.

Second best solutions:

Coalition structure ($A+B; C+ D$), the costs of the second best solution: 35 + 70 = 105.

Coalition structure ($A+B; C; D$), the costs of the second best solution: 35 + 50 + 20 = 105.

Third best solutions:

Coalition structure ($A+C; B+D$), the costs of the solution: 70 + 40 = 110.

Coalition structure ($A+D; B+C$), the costs of the solution: 50 + 60 = 110.

Coalition structure ($A+ B+D; C$), the costs of the solution: 60 + 50 = 110.

Coalition structure ($B+C; A; D$), the costs of the solution: 60 + 30 + 20 = 110.

The subjects-polluters in the experiments were paid for showing up and 3 successful groups in each of the cohorts were paid extra money at the amount of the surplus they negotiated. A formula of $Srq-S_{min}$ was used for calculating the amount of the extra fee paid to the participants. The subjects in the role of polluters-managers were given the following materials (see attachment for more details):

– The situation (case) description;

– Training (2-subject case; non-confidential) data for better understanding the experiment;

– Confidential data for the experiment (s);

– Application form for requesting financial support from the authority.

The subject playing the role of the authority (the authors of this paper) had the same materials as the subjects-polluters plus the description of details of the experimental process to keep the same conditions in all conducted experiments.

As for the experiment instruction and procedure, the subject playing the role of the authority distributed the materials, made a picture of the situation on the blackboard and explained the case, demonstrated the managers' decision-making process on the training data on 'hypothetical' polluters X and Y, gave about 20 minutes for negotiations among the participants and collected the completed application forms for financial support from the subjects at the end of the experiments. He also informed the subjects that there is one round of application possible, that the financial resources for financial support are limited (i.e., not all applications can be supported) and that the subjects would be financially rewarded after the experiments. He asked if the instruction was understandable and answered potential questions (in principle repeating the same instruction; if necessary using different words/synonyms). He paid its subjects the experimental money shortly after the experiment. The instruction (both written and oral) in the experiments conducted in the Czech Republic was provided in Czech language. As for the experiment in Ukraine, the written information was provided in English (see attachment), the oral information was provided in Russian. There was no blackboard or similar equipment in the room in Ukraine, so the oral instruction could not be supported with the hand-made picture.

4. Experiment results and discussion

In total, 80 subjects playing the roles of managers-polluters took part in the experiments: 48 bachelor and master students of UEP Prague (12 June 2013), 16 bachelor students of the College of Polytechnics Jihlava (22 April 2013) and 16 participants of the XIIth International Research Seminar "Contemporary Issues of Information Science in Management, Economics and Education" Svityaz (Volyn, Ukraine) (3 July, 2013).

Table 1. **Results for the cohorts from UEP Prague,** *calculated by the authors*

Group	Coalition structure	Support
Cohort I		
1	(A+B+C+D)	160
2	(A+D, B+C)	80 + 150 = 230
3	(A+C, B+D)	160 + 100 = 260
4	(A+D, B+C)	75 + 105 = 180
Cohort II		
5	(A+B+C, D)	110 + 30 = 140
6	(A+B+C+D)	200
7	(A,B,C,D)	40 + 45 + 80 + 45 = 210
8	(A+B, C, D)	80 + 70 + 40 = 190
Cohort III		
9	(A+B+C+D)	1000 (?)
10	(A+C, B+D)	150 + 90 = 240
11	(A+B, C+D)	40 + 75 = 115
12	(A+B, C+D)	45 + 78 = 123

Table 1 shows the results for the 3 cohorts (12 groups) of UEP Prague. Of these 12 groups, one group formed the optimal coalition structure; 3 groups formed the second-best structures and 4 groups formed the third-best structures. The extreme financial support requirement of group no. 9 (1000 units) is the result (as mentioned by the experiment participant in the follow-up discussion) of the subjects in this group misunderstanding the instruction.

Table 2 shows the results for the 4 groups of subject at the Jihlava Polytechnics. Of these 4 groups, 2 groups formed the optimal structures; one group formed the second-best structure.

Table 2. **Results for the cohort from Jihlava,** *calculated by the authors*

Group	Coalition structure	Support
Cohort IV		
1	(A+C+D, B)	110 + 37 = 147
2	(A+B, C+D)	45 + 90 = 135
3	(A+B+C, D)	110 + 25 = 135
4	(A+B+C, D)	100 + 30 = 130

Table 3. **Results for the cohort from workshop in Svityaz,** *calculated by the authors*

Group	Coalition structure	Support
Cohort V		
1	(A+B+C+D)	240
2	(A+B +D, C)	120 + 60 = 180
3	(A+C, B+D)	140 + 60 = 200
4	(A+B+C, D)	160 + 40 = 200

Table 3 shows the results of the 4 groups of the experiment organized at the International Research Seminar in Svityaz. Of these 4 groups, 1 group formed the optimal structure; 2 groups formed the third-best structures.

The participants at the experiment in Svityaz mentioned a language problem when being explained the instruction and a relatively short time for the experiment. This might also explain their higher average request for financial support – 205 in Svityaz compared to 186.2 at UEP (not including the extreme) and 136.8 in Jihlava.

5. Conclusions

The comparison of the results at the 3 places where the experiment was organized shows no significant differences in the selection of good coalitions. The Jihlava Polytechnics seems to be slightly better from this point of view. There are considerable deviations in the requested support. Here the subjects from Jihlava demanded by far the lowest support with a strong awareness that not all requests would be accommodated. This can be explained by the fact that the subjects from Jihlava participated in similar experiments in the past.

The threat that the group, and thus all the subjects in it, would not be included in the optimal program and would not receive the financial support most likely did not always function though the subjects received a financial reward in the experiment.

It is possible to expect that multiround negotiation would work better, i.e., more groups would find the first best solution and the required financial support would be closer to the cost-effective solution, as happened in the experiments described in Sauer et al. (2003). The other question for future experiments is whether and how to provide the participants with feedbacks in the auctions (see Katuscak et al., 2013).

The results inspire us to continue experiments with a richer structure of coalitions with multiround negotiations under pressure and the introduction of multicriteria evaluation of environmental and other effects performed by authorities when solving the problem of how to reduce pollution in a region cost-effectively.

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