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Models of Interaction of Providers of Satellite Services and Consumers as Participants of the Space Market

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***Abstract*—The active growth of the commercial sector of the space market makes it relevant to the issue of development of existing methods of simulation of interaction of participants of the market between providers of satellite services and end-users taking into account its specificity. The subject of the research is the economic processes in the space market that take place in the framework of interaction between satellite service providers and end users. The aim of this work is to develop a methodology for the formation of optimal contractual relations between the participants of the space market, taking into account the possibility of asymmetry of information and allows to optimize the decision-making process for the party offering the contract.**

Within the framework of the structure, the authors propose options for models for building contract relations between satellite service providers and end users in the conditions of symmetric and asymmetric information structures with the use of elements of the theory of contracts. The approach to the determination of optimal parameters of contracts presented in the article can be applied as a tool to support management decision-making for space market participants.

Keywords—World Space Market, Consumer, Theory Of Contracts, Information Symmetry And Asymmetry.

I. INTRODUCTION

The role played by institutional and military customers in shaping the development of the space industry has long been acknowledged by scholars (e.g. McDougall, 1982). From the very beginning of the space era, government agencies (e.g. NASA, Roskomos, CNES or ESA) and military organisations (e.g. Ministries of Defence, Air Forces, Defence Acquisition Agencies) provided direct support for the construction of space infrastructures, including ground stations, launchers and satellites facilities, and for the development and diffusion of space-related knowledge and capabilities. Formation of models of interaction of participants of various levels of structure of the space market is based on the basic principles of models of the theory of contracts (Salanie, 2005). The model for a case of existence of asymmetric information means finding of the optimum contract by imposing of the restrictions on incentives described in Mayerson and Sattertueyt's work (Myersonetal., 1983). Functions of usefulness are chosen for providers of satellite services so that for them Spence-Mirrlis's condition (a condition of single crossing) was satisfied (EdlinandShannon, 1998).

II. CONCEPTUAL FRAMEWORK

At first we will consider the general scheme of process of formation of the contract relations between participants of the first level of structure of the space market – providers of satellite services – and end users (figure 2). In the considered model, following terminology of the theory of contracts, we will designate provider of space services for the principal, and end users of space services – for agents. The scheme covers two possible information structures of the market: symmetric and asymmetric. In case of symmetric information the provider distinguishes consumers and establishes the menu of contracts on the basis of this information. In case of asymmetric information structure provider, without knowing types of consumers, creates the mechanism of formation of the menu of contracts meaning input of a certain system of restrictions. Use of the entered conditions allows to put consumers in a situation when the individual contract intended for their real type brings them more benefit: higher types buy goods at the bigger price, but receive the effective volume of services, for the lowest types the price is lower, however they don't receive the volume of satellite services, optimum for them (Skorobogatov, 2006).

At this level of structure of the space market demand of different types of consumers for space services forms total demand for a certain volume of space services of D (p). Having estimated the level of this requirement, providers of space services determine for themselves the size of information capacity which is capable to satisfy consumer demand and which they can realize at the financial opportunities. Costs of provider of satellite services for unit of the service offered consumers are equal with. Depending on the expenses and demand for space services the provider offers consumers the contract as which parameters support the price unit of service of p and volume of satellite services x.

Let's say consumers of space services are divided into two types: $\theta 1$ and $\theta 2$, besides the share of consumers of the first type makes π, and the second – $(1-\pi)$. The usefulness of the consumer of the first type is described by the equation

$u_1(x_1, T_1) = \theta_1 v_1(x_1) - T_1$ where monetary assessment of acquisition of satellite services has an appearance, $v_1(x_1) = a_1 x_1^2 + b_1 x_1$, a1and b1-numerical coefficients (Djusushe, 2003). The usefulness of the consumer of the first type is described by the equation $u_2(x_2, T_2) = \theta_2 v_2(x_2) - T_2$,where monetary assessment of acquisition of satellite services has an appearance $v_2(x_2) = a_2 x_2^2 + b_2 x_2$, the a_2 and b_2 - numerical coefficients. Expenses of the consumer of the first type are described by the equation $T_1 = px_1$, and the consumer of the second type - $T_2 = (1-\mu)px_2$ in a type of the fact that large volumes of the order are characteristic of him, and it grants to him the right to a discount μ.

It is supposed that the provider of satellite services is a monopolist in the market of space services as offers an exclusive type of satellite service.

Criterion function of provider of satellite services has an appearance:

$$\Pi_i = (p_i - c) \cdot D_i(p_i) \to \max_{p_i} \quad (1)$$

Demand of the consumer of i-type is defined from the solution of a task $u_i = \theta_i v_i(x_i) - px_i \to \max_{x_i}$ (Golovan' etal., 2005).

For the first type of the end user of space services the task looks as follows: $u_1 = \theta_1(a_1 x_1^2 + b_1 x_1) - px_1 \to \max_{x_1}$ for the second type, respectively $\theta_2(a_2 x_2^2 + b_2 x_2) - (1-\mu)px_2 \to \max_{x_2}$.

For the solution of a problem of maximizing usefulness of the consumer of i-go of type the condition of the first order is satisfied:

$$\frac{\partial u_1}{\partial x_1} = 2\theta_1 a_1 x_1 + \theta_1 b_1 - p = 0.$$

$$\frac{\partial u_2}{\partial x_2} = 2\theta_2 a_2 x_2 + \theta_2 b_2 - (1-\mu)p = 0$$

At the solution of each equation the optimum volume of satellite services provided by provider for each type of the consumer is defined:

$$x_1 = \frac{p - \theta_1 b_1}{2\theta_1 a_1} \quad (2)$$

$$x_2 = \frac{(1-\mu)p - \theta_2 b_2}{2\theta_2 a_2} \quad (3)$$

Further the need for satellite services for each type of the consumer is expressed:

$$D_1(p) = \begin{cases} \frac{p - \theta_1 b_1}{2\theta_1 a_1}, 0 \le p \le \theta_1 \\ 0, p > \theta_1 \end{cases} \quad (4)$$

$$D_2(p) = \begin{cases} \frac{(1-\mu)p - \theta_2 b_2}{2\theta_2 a_2}, 0 \le p \le \theta_2 \\ 0, p > \theta_2 \end{cases} \quad (5)$$

Finding of the consumer of the price, individual for each type, for unit of satellite service assumes substitution of the corresponding expression of demand (4) and (5) in criterion function of provider of services (1) and her further differentiation at the price (Belyaeva, 2017). Thus, the individual prices will have an appearance:

$$p_1 = \frac{\theta_1 b_1 + c}{2} \quad (6)$$

$$p_2 = \frac{\theta_2 b_2 + c(1-\mu)}{2(1-\mu)} \quad (7)$$

So, optimum parameters of individual contracts for each type of the consumer in the conditions of symmetric information are as a result found.

We will consider the second option of information structure – asymmetry. We will include the following restrictions due to which on terminology of the theory of contracts the principle of identification of types of agents is implemented in modified criterion function of provider of satellite services (in our case, two types of consumers):

$$\Pi = \pi(p_1 - c)x_1 + (1-\pi)(p_2 - c)x_2 \to \max_{p_1, p_2, x_1, x_2} \quad (8)$$

$$\begin{cases} \theta_1(a_1 x_1^2 + b_1 x_1) - p_1 x_1 \ge 0 & (9) \\ \theta_2(a_2 x_2^2 + b_2 x_2) - p_2 x_2 \ge 0 & (10) \\ \theta_1(a_1 x_1^2 + b_1 x_1) - p_1 x_1 \ge \theta_1(a_2 x_2^2 + b_2 x_2) - p_2 x_2 & (11) \\ \theta_2(a_2 x_2^2 + b_2 x_2) - p_2 x_2 \ge \theta_2(a_1 x_1^2 + b_1 x_1) - p_1 x_1 & (12) \end{cases}$$

Inequalities (9)-(10) are participation restriction conditions, due to their introduction in the mechanism of determination of optimum parameters of the contract to both consumers becomes unprofitable to refuse the transaction. Conditions of restriction of compatibility on incentives (11)-(12) give a guarantee that both consumers will prefer contracts with the individual parameters intended for their type due to obtaining bigger usefulness at the choice of "the" contract than "stranger" (Bakeretal., 2002).

In an optimum point restriction (9) addresses in equality. Restrictions (10)-(11) in a point of the optimum contract are inefficient and therefore they can be not included in an optimizing task (BremzenandGuriev, 2006). Then the expressions describing the price, individual for each type of the consumer, for service unit will have an appearance:

$$\Pi = \pi(p_1 - c)x_1 + (1-\pi)(p_2 - c)x_2 \to \max_{p_1, p_2, x_1, x_2}$$

$$\begin{cases} p_1 = \dfrac{\theta_1(a_1 x_1^{\,2} + b_1 x_1)}{x_1} \\ p_2 = \dfrac{\theta_2(a_2 x_2^{\,2} + b_2 x_2) - \theta_2(a_1 x_1^{\,2} + b_1 x_1) + \theta_1(a_1 x_1^{\,2} + b_1 x_1)}{x_2} \end{cases}$$

Further the found prices are substituted serially in criterion function of provider (8) then for the purpose of scoping of services the condition of the first order is formed. From him we receive the optimum offer of volume of satellite services for consumers of both types:

$$x_1 = \frac{\pi(c - b_1\theta_1) + (1-\pi)(\theta_2 b_1 - \theta_1 b_1)}{2(\pi\theta_1 a_1 - (1-\pi)(\theta_2 a_1 - \theta_1 a_1))}$$

$$x_2 = \frac{c - \theta_2 b_2}{2\theta_2 a_2}$$

Thus, optimum values of parameters of contracts for consumers of both types in the conditions of symmetric and asymmetric information are found.

III. CONCLUSION

Thus, the principle of-level structuring the space market is reflected in work. On the basis of the built levels models of interaction between provider of satellite services and consumers of these services are constructed. Consideration of these models in-level interrelation with each other allows to create uniform methodical approach to modeling of the space market in general that can promote optimization of process of interaction of its participants and also coordination of their interests. It is noted that the first level describing interaction of provider of satellite services and end users of space services exerts impact on all commercial sector of the market, including on the directions of technological and production development of producers of spacecrafts and launch vehicles.

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