Paradoxical Behavior of Production Sharing Participant

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We consider a mining or other extractive project, which is fulfilled on the basis of a production-sharing agreement. These agreements provide for production sharing on the basis of current IRR or current R-factor. The implications of using such production sharing mechanisms are studied with the help of simple economic-mathematical models. It appears that in some cases these mechanisms stimulate paradoxical behavior of the investor. For example, those variants of a project which require higher investments but return same yields happen to be more advantageous to the investor; and similar are those variants which provide smaller yields with the same investments.

Key words: production sharing, agreements, mechanisms, efficiency, investor's behavior, paradoxes.

JEL classificarion: H32, H25, L71

Since the early 90-ies of the last century production-sharing agreements (PSA) are widely debated in our country. A variety of views on these agreements are presented, for instance, in (Arbatov, Konoplyanik, 2007; Subbotin, 2007). In particular, many authors pay attention to the real or fictitious facts of deliberate overvaluation of costs by firms carrying out the development of a field under the production sharing agreement (production-sharing participants, henceforth). For instance, G.Waller, director of the Petroleum Advisory Forum, in his 1999 article "Production-sharing in Russia – myths and reality" points out such situations are hardly in line with the rules of rational economic behavior (cited from (Arbatov, Konoplyanik, 2007):

"In the PSA environment companies make profits from the maximum possible increase in the share of profit oil, rather than recovering of the costs. There is a physical limit to the quantity of oil, which can be extracted from this field. The more compensatory oil, the less profit oil happens to be. The less profit oil, the less is profit both for the investor and the State.

Cost recovery means that a company has returned a dollar on every invested dollar. The real future value of the funds is less than the investment today, since these funds would yield an interest if they were invested in any other project. This economic concept known as "discounted" or "current" value proves it is impossible to make profit from the only cost oil.

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We also heard suspicions that companies would try to shift costs to affiliated contractors in order to increase the share of cost oil as much as possible. There is no evidence to support those suspicious, though. It is possible to develop mechanisms such that companies couldn't engage in unethical actions. One may conduct audit of contractor's agreements by reputable audit firms.

It is for the sake of both investor and the state to streamline costs and maximize profits--standing at the same time for the highest ethical norms, the highest rules of conduct, public health, accident prevention and environmental protection."

Meanwhile the above arguments are not convincing since it is implicitly assumed that a decrease in total quantity of profit oil simultaneously and in the same proportion decreases the profit of the investor.

It would seem, the possibility of the opposite situation is purely hypothetical and does not occur in practice. Alas, this is not true. Having investigated the situations which have arisen in a number of PSA projects implemented in Russia, we found out that in some cases for the production-sharing participant, acting in accordance with legal, technical and ethical standards, it appears favorable to inflate costs[3] and to abandon activities that would provide additional income. Such a behavior we called paradoxical and decided to find out whether it is exceptional.

The study showed that such paradoxical situations are possible under certain conditions and this possibility is due to the nature of the common terms of output division in the PSA, namely – dependence of the output share on investor's revenues and expenses accumulated over the period prior to the division (with or without discounting). The findings are of general nature and apply equally to Russian PSAs as well as PSAs undertaken in other countries (including agreements with foreign states that Russian companies may enter). The fact that the purpose of the PSA is to develop just an oil or oil and gas field does not play any crucial role – the findings apply as well to the development of other mineral fields and even completely different activities.

The general idea of the article may be explained by two model examples, highlighting critical to our objective, distinctive features of many practicable PSAs or those recommended in the literature. We consider two sharing criteria recommended by, for example, (Johnston, 2005) and used in already concluded PSAs[4]: current internal rate of return (current IRR) and the so called R-factor. Economic content of these criteria is disclosed below.

In all examples the field development process is considered in continuous time.

[3] Obtaining additional income at the expense of "shifting" additional costs to affiliated contractors, we believe, violates ethical standards and is not considered in the article.

[4] By the way, the Federal Law on Production Sharing Agreement, which is currently in force in Russia, does not define any mandatory criteria of sharing, but somehow restricts its scope.

The following scheme will be common to all examples. PSA provides for a lump-sum investment cost K at time 0, and then mining begins immediately. Annual oil production, annual sale revenue P and annual operating costs on mining Z are taken as constant. The difference $D=P-Z$ will be annual operating income from the development of the field (total operating income). This income[5] is divided between the firm and the state according to a certain rule (the rule differs in different examples). To simplify the computations the length of the development period is considered to be infinitely large.

The firm assesses the advantage or disadvantage of its actions applying the net present value (NPV) criterion at the firm's discount rate r. This criterion is completely market-driven, it is used by many firms and, as can be shown, it ensures the maximization of the future market value of the firm.

The terms of production sharing in both examples are typical in a sense that the investor's share in the volume of shared output changes over time (from the maximum level in the beginning period followed by a jump decrease depending on the sharing criteria).

The production sharing criterion in the first example will be the current internal rate of return (current IRR). In accordance with officially approved Methodical recommendations (2000, section 2.8) it is defined as a number i, such that the net present (at this rate) value of the previous period investment is equal to 0 given the discount rate equal to i, negative for higher rates, and positive for the rates lower than i.

Example 1. It is assumed the firm receives all the total income unless the operating income accumulated over the previous period is equal to the lump-sum investment cost K. Further down the line, the firm receives a share of total income g unless the current internal rate of return of the profit flow exceeds the limit ρ fixed by the PSA (it may be treated as a **separating** discount rate). After that the firm's share in total income decreases to the level h.

Thus the field development process here consists of three periods: compensatory (till the full recovery of the initial investment), the primary profitable (when the firm's share in total income equals to g) and the subsequent secondary profitable period.

The above terms of the PSA allow obtaining analytical expressions for time-varying parameters of the process.

In the compensatory period annual net income of the firm will be D, so the length of this period θ can be found by equating income received by the firm to the volume of lump-sum investments:

[5] The fact that the firm pays royalty to the state before the division of output does not affect our conclusions. If necessary, royalty can be taken into account by treating P as revenues minus royalty.

$$D\theta = K\,. \tag{1}$$

In the next primary profitable period firm's annual net operating income will be *gD*, so the end of this period τ is found by equating to zero the net present value (calculated under the separating discount rate ρ) over the period [0, τ]:

$$-K + \int_0^{\theta} De^{-\rho t}dt + \int_{\theta}^{\tau} gDe^{-\rho t}dt = 0\,.$$

Hence, after taking the integral and performing simple transformations taking into account (1), we obtain:

$$e^{-\rho\tau} = \frac{1-\rho\theta-(1-g)e^{-\rho\theta}}{g}\,. \tag{2}$$

In the subsequent secondary profitable period annual net operating income of the firm will be *gD*. This allows to compute the firm's NPV of participation in production sharing:

$$\begin{aligned} NPV &= K + \int_0^{\theta} De^{-rt}dt + \int_{\theta}^{\tau} gDe^{-rt}dt + \int_{\tau}^{\infty} hDe^{-rt}dt = \\ &= -D\theta + D\frac{1-e^{-r\theta}}{r} + gD\frac{e^{-r\theta}-e^{-r\tau}}{r} + hD\frac{e^{-r\tau}}{r} = \\ &= \frac{D}{r}\left\{1-r\theta-(1-g)e^{-r\theta}-(g-h)e^{-r\tau}\right\}. \end{aligned} \tag{3}$$

Using equation (2), this formulae can be written as:

$$NPV = \frac{D}{r}F\,, \tag{4}$$

where

$$F = 1-r\theta-(1-g)e^{-r\theta}-(g-h)\left[\frac{1-\rho\theta-(1-g)e^{-\rho\theta}}{g}\right]^{\frac{r}{\rho}}. \tag{5}$$

Function $F(\theta)$ for ρ = 0,16, r = 0,08, g = 0,9 and varying h is presented in Fig.1. Fig.2 shows the same function for g = 0,7. The diamonds on the graphs indicate points where the function becomes increasing. The graphs are cut off at such values of θ that the fixed separating value ρ=IRR is not achieved over any final period, i.e. equation (2) has no solution and the secondary profitable period does not occur.

Fig.3 represents the same function for g =0,9, h =0,4 and varying ρ.

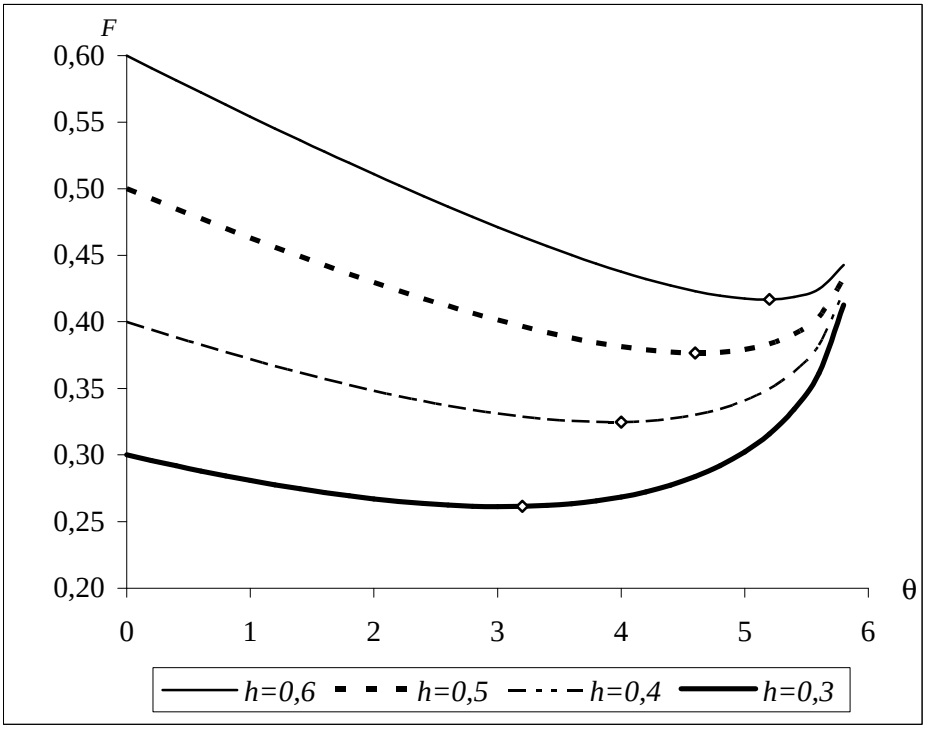

Fig.1. **Function *F*(θ) for ρ=0,16, *g* =0,9**

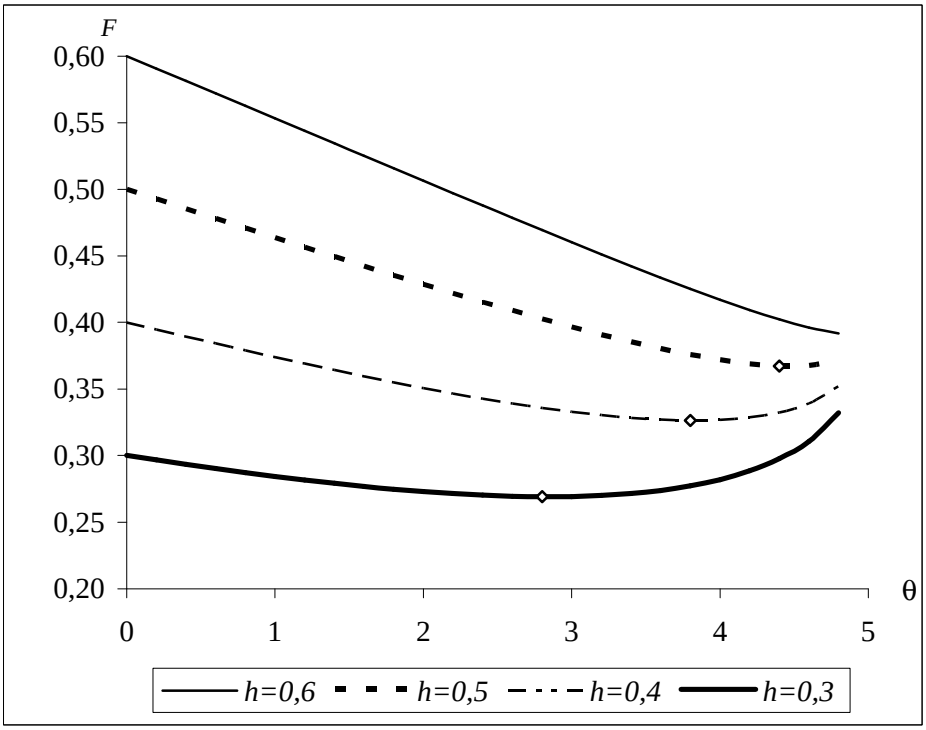

Fig.2. **Function *F*(θ) for ρ=0,16, *g* =0,7**

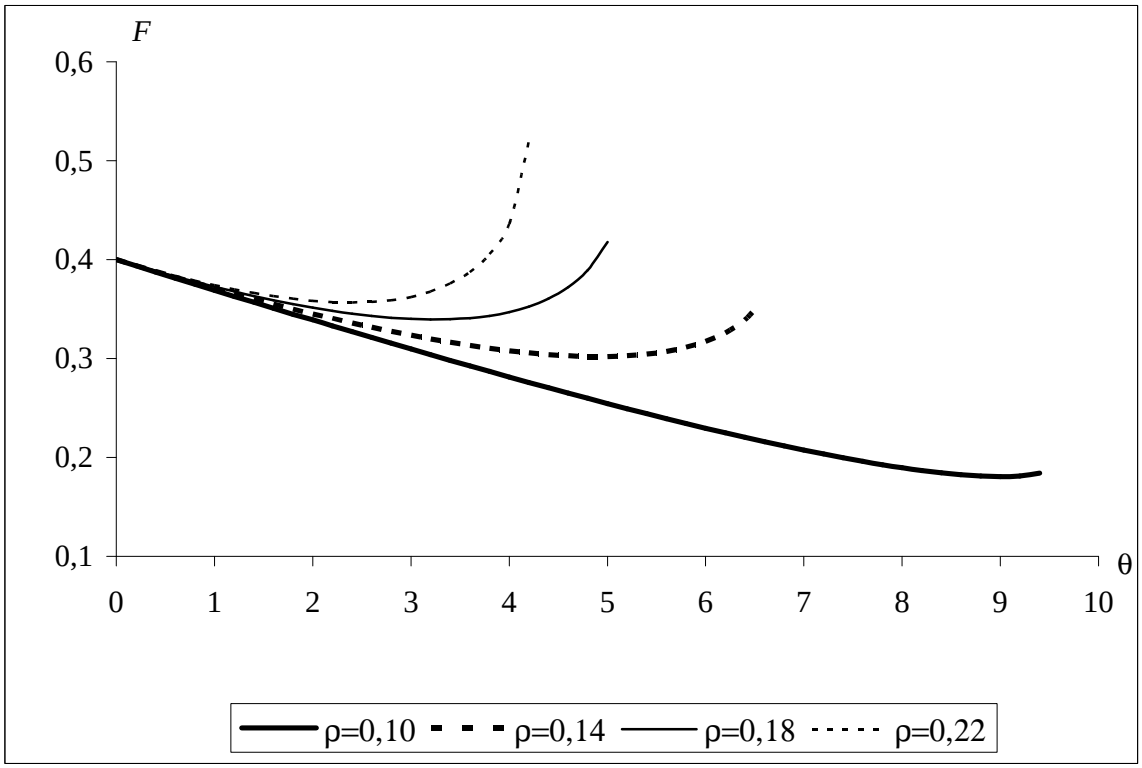

Fig.3. **Function *F*(θ) for *g* =0,9, *h* =0,4**

Evidently, with the growth of θ function *F*(θ) first decreases, and then sometimes starts growing.

Consider now the case when the firm may choose between different construction patterns of **the same (i.e. identical in terms of their operating characteristics) engineering structures** in the field, for example, by employing different technologies and engineering of well-drilling and in construction of land-based structures. It would be rational for the firm to prefer a project requiring less investments. It turns out such a conclusion may be mistaken. Indeed, to the project with higher investment costs *K* (and the same annual operating income *D*) will correspond the longer compensating period θ=*K*/*D*, and with the increase of θ, as we have seen, NPV of the firm's income flow may grow. In other words, choosing the best construction project the firm may prefer a more capital-intensive one. We emphasize the matter does not concern getting benefits "on the side", but the firm's objective to improve the effectiveness of participation in the development of the field, and finally – to maximize its market value. Such commercially reasonable behavior of the firm, substantially different from "rational" behavior of any business corporation under the "regular" tax system, could be called paradoxical. Thus, we found that,

under the above terms of production sharing, the investment behavior of the firm may be paradoxical.

Let us continue with the example and now consider another case when the investor after starting a project appears to increase its total operating income *D* (it can be achieved for example by changing the production technology leading to lower operating costs, or by an increase in output). In such a case the volume of initial investment does not change, whereas an increase in *D* leads to reduction in the length of the compensatory period $\theta = K/D$, and equation (4) becomes: $NPV = \frac{K}{r} \cdot \frac{F}{\theta}$. The dependence of the ratio F/θ on θ for r =0,08, g =0,9, h =0,4 and varying ρ is presented in Fig. 4.

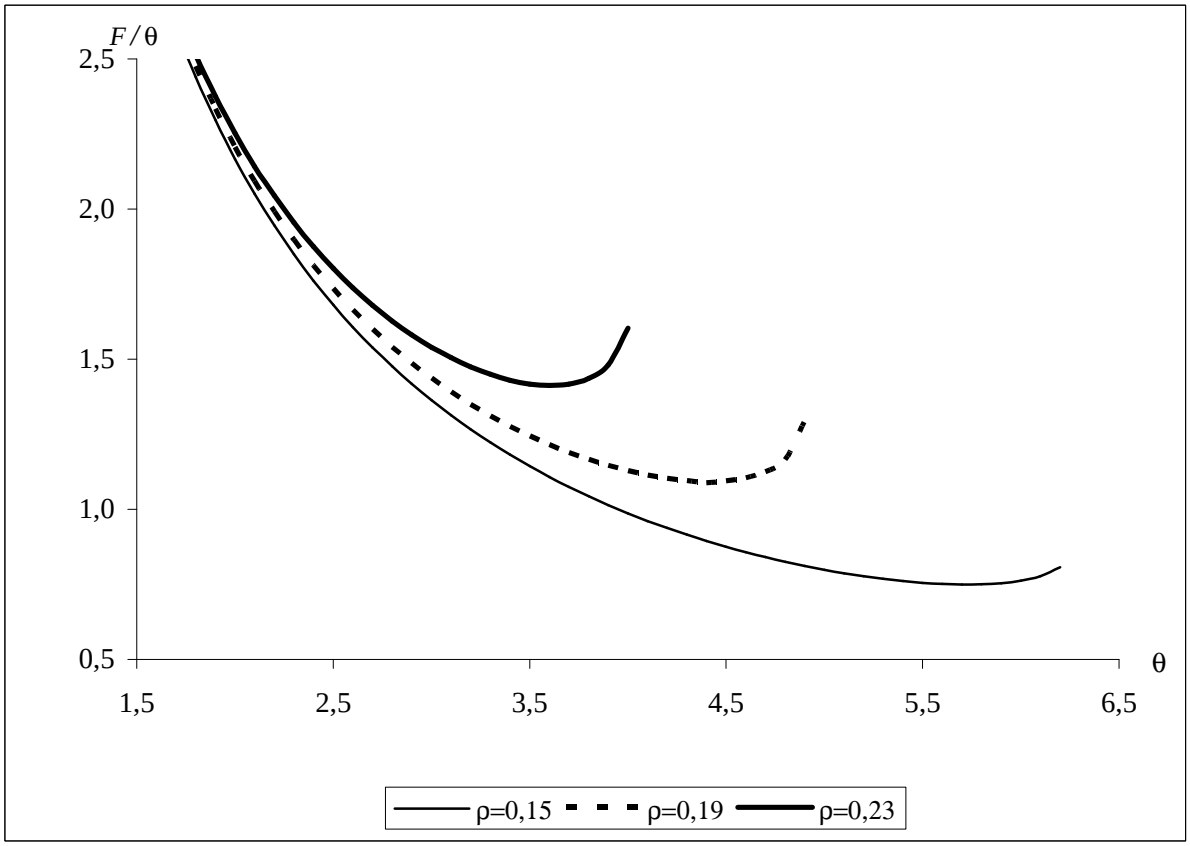

Fig.4. **Function F/θ for g =0,9, h =0,4**

As we can see, the ratio F/θ, and, hence, the NPV of the firm may decrease with a decrease of θ in a certain range. This means that some activities that would be certainly implemented under the "regular" tax system become unprofitable for the firm.

The above figures demonstrate that such phenomena are possible, though not at any particular ratio between initial investment and annual operating income. However, if the ratio lies in a certain range of values (which depends on other parameters of the production sharing mechanism and may be wide enough), such situations appear to be possible, and by no means exceptional (such as double roots of the quadratic equation with random coefficients). Put differently, once they arise, they persist even under small changes of technical and economic indicators of the project or production sharing parameters. Therefore, if the paradoxical behavior of the investor is likely to appear in practice, it will be hardly eliminated by any moderate adjustments to the PSA terms, even if they might have been introduced into the signed agreement.

The reason for the paradoxical behavior, in our opinion, lies in the PSA foundation terms themselves, i.e. the very principle of production sharing under which the investor's share changes depending on his/her accumulated incomes and expenses; it is not to be thought that the situation is merely caused by inopportune choice of specific values of these shares or other production sharing parameters (in this case – the separating rate of return).

We will obtain the same result in the next example as well, where the production sharing criterion will be not the IRR, but the so-called R-factor – the ratio of accumulated (undiscounted) incomes and field development expenses. Different PSAs specify such incomes and expense thresholds differently. In this example we will include in project costs both the lump-sum investments and current operating costs, while total output sale revenues will count as income.

Example 2. The firm receives the entirety of its total income until such time when its cumulative operating income surpasses the volume of incurred lump-sum investment costs K. After that the firm receives a share g of the total income until the R-factor is equal to the separating value R fixed in the PSA. The firm's share in total income decreases to the level h thereafter.

As in the previous example, the process of field development here consists of three periods: compensatory (till the full recovery of the investment costs), the primary profitable period (when the firm's share in total income equals g) and the subsequent secondary profitable period. The length of the compensatory period θ is given by the same equation (1). To find the end of the primary profitable period τ, note that up to this moment the firm will incur total (i.e. investment plus operating) expenses $K+Z\tau$ and recieve income $P\tau=(D+Z)\tau$. At τ the ratio of

cumulated incomes to cumulated expenses should coinside with the treshold value R of the R-factor. Thus, τ must satisfy the equation: $\frac{(D+Z)\tau}{K+Z\tau}=R$. From this, denoting $Z/D=u$, we find:

$$\tau=\frac{R}{1-(R-1)u}\theta. \qquad (6)$$

Equations (3) and (4) for NPV of the firm hold true, though the coefficient F in (5) will be given by:

$$F=1-r\theta-(1-g)e^{-r\theta}-(g-h)e^{-\frac{Rr\theta}{1-(R-1)u}}. \qquad (7)$$

Fig.5 presents the function $F(\theta)$ for g =0,9, h =0,4 and varying R.

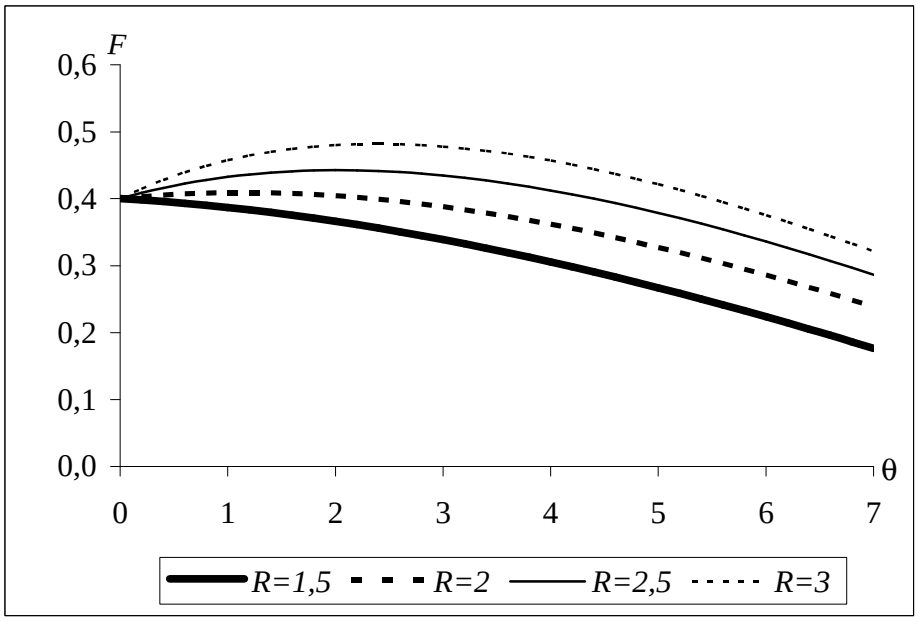

Fig. 5. **Function $F(\theta)$ for g =0,9, h =0,4.**

Similar to the previous case, for large enough values of R an increase in capital investments leads to an increase in NPV of the firm. In other words, paradoxical behavior of the production sharing participant is possible under this sharing mechanism as well.

The matter doesn't change radically if we consider only the net income of the firm in order to determine the R-factor. Here by the end of the primary profitable period the accumulated net income will be $D\theta+gD(\tau-\theta)$. So we have the following equation $\frac{D\theta+gD(\tau-\theta)}{K+Z\tau}=R$ to find $\tau=\frac{R-1+g}{g-Ru}\theta$. In comparing this to the equation (6), we can

observe that only the coefficient before θ has changed, so the nature of the result should not change. However it is possible to ascertain the result by plotting the corresponding analytical expressions.

Paradoxical behavior of the investor seems possible as well if one compares discounted (i.e. calculated under the investor's individual discount rate *r*) incomes and expenses of the investor while computing the *R*-factor. The equation for τ becomes more complicated, but the function $F(\theta)$ for large enough values of *R* will be increasing as well in a certain range of θ-values.

Thus, behavior of the firm may be paradoxical at some values of quantitative parameters in a certain production sharing mechanism. In such a case it may be profitable for the firm to introduce inefficient (from the point of view of the "ordinary" market participant) equipment or technology. Indeed, market considers a equipment or a technology to be efficient only if it yields the rate of return on the investment higher than the discount rate. Meanwhile, if there exists a equipment or a technology yielding smaller return on the investment, the use of it will lead to a nearly same effect as simply making "unnecessary" additional investment. Therefore application of such inefficient technology will turn out to be profitable for the production sharing participant.

Of course, the above examples are of a model nature. On their basis there have been built more realistic models taking into account such additional specificities of the PSA as taxes and time-varying output volumes and operational costs. But the corresponding analytical expressions become significantly more complicated, and in a number of cases one has to make numerical rather than analytical estimations, however the overall result remains the same. Even considering the investor's share as a continuous function of a particular criterial indicator "does not help". The reason is likely that the choice of production sharing mechanism is made under incomplete information about geological structure of the field, the volume of reserves as well as about technical and economic indicators of the development process. Because of this, the preference is given to adaptive mechanisms of production sharing that adjust to the changing environment of the project. For this reason production sharing factors in such mechanisms are set as variable quantities which depend on accumulated incomes and expenses of the investor. Moreover, the desire of the state to obtain an increasing share of profit output is understandable as well. Thus, any sharing mechanism tends to accommodate investor's share which decreases with his/her accumulated income and increases with his/her accumulated expenses. However, it is exactly this dependence typical for all PSAs which creates the possibility of paradox behavior of the investor: by accumulating costs the investor postpones time to proceed to a lower share of profit output. Thereby, the investor will get higher share of profit output over a longer period of time.

The related total "gain" of the investor may be smaller than his/her additional costs in some cases, but larger – in others, what has just been shown in our simplified models. It's worth mentioning that such a matter is found as well in one of the projects implemented under a PSA in Russia.

We do not consider ourselves as PSA opponents, moreover, we believe it is necessary that this and other forms of public-private partnership be much more widely used in Russia. Nevertheless, the revealed feature of considered production sharing mechanisms shows that the choice of quantitative parameters of a PSA should be treated with a great caution, since existing ways of production sharing do not preclude a situation where the investor gains by inflating costs. Usually, at the preparatory stage preceding the agreement one considers a variety of scenarios for its implementation and calculates the corresponding cash flow (see, for example, (Bogdanchikov, Perchik, 1999, chapter 5). However, the attention is primarily focused on the volume of state revenue and that of the investor. In our opinion, while making scenario computations it is necessary in addition to check whether a particular mechanism of production sharing creates incentives for paradoxical behaviour of the investor[6], and if needed – to change the terms of the designed agreement in order to avoid such situations.

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[6] Technically, this is easily done: having calculated the cash flow for a particular scenario, we can estimate the net present value (NPV). Then we can consider the second variant of this scenario corresponding to a somewhat larger amount of expenses in a given time period, and find out whether the NPV has increased. Such calculations are similar to those of stability of a project, which are mandatory in terms of their inclusion.