Jul 1st, 12:00 AM

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The conventional implementation of polluter pays principle (PPP) in many countries is based on the use of an environmental tax, which is determined proportionally to the amount of emissions of the polluting substances. Using a specific mathematical model this study shows that this practice is not adequate for the real negative impact if the pollutant accumulates to a stock in the environment. Moreover, in many cases there is a danger of an unavoidable conflict between the interests of society as a whole and the interests of private business, generated by these procedures of PPP implementation. This paper also presents a mathematical formula (obtained as an analytical result) which expresses the time period, when the conflict arises, therefore it is called "the time boundary of investment expediency". On the basis of the model analysis, "a corrected" amount of environmental tax which covers the negative effect on social welfare is suggested. One of results of the model analysis demonstrates that this tax should be dependent on the lifetime of the production project, not only on the amount of emitted pollution. This approach allows to construct specific information system for the calculation of several indicators which provide quantitative characteristics for evaluation of production projects (eco-intensity, eco-efficiency, interests on ecological debt etc.). The information system can be used for comparative analysis of different investment projects and for the forecast of the consequences of decision taken. The study gives also some practical tools for strengthening governance in the environmental sector and for the evaluation of investment initiatives from a "quality of growth" point of view.

***Keywords*:** polluter pays principle, stock pollution, conflict of interests

1. INTRODUCTION

A conceptual analysis of long-run decisions about the economy and the environment as an application of capital theory has been presented in the papers of Faber et al, (1998), Baumgartner et al (2002). The authors show that if a pollutant accumulates to a stock in the environment, then there is an intertemporal leverage effect to the associated social cost of pollution, depending on the lifetime of the pollutant. They used a specific mathematical model where degradation rate of the pollutant and per unit social cost are the parameters. When analyzing this model they concluded that in this case (stock pollution) the longer the time horizon, the less likely is the innovation of the new technique.

This conclusion has been made under a very important assumption: all social costs that society incurs due to the damage from pollution are taken into account within the investment decision making. It is a crucial idea of this paper's background. We found that a similar effect plays the key role for potential conflicts between society and business in long-run decisions. For our analysis we used the model from Baumgartner et al, 2002 with a few modifications for our purposes.

According to environmental legislation in Russia and in some other countries the polluter must pay to the state budget proportionally to the amount of emissions. It is a kind of environmental tax; its size depends on the harm from the specific polluting substance. At the same time producers must make their own efforts to reduce pollution, in order to avoid the penalty for emissions exceeding the permitted (by environmental standards) level. In our consideration we denote by g the environmental cost of the producer, including the environmental tax (per unit of emission).

The problem of economic growth is crucial for transition economies. The first reason of this is the goal of overcoming poverty. However it is well known that growth might be unsustainable. We cannot ignore the fact that the poverty is an essential factor of environmental decay in Russia. An illustration of this insight is the process of the apparent degradation of Russian forest ecosystems. Industrial development increases welfare, but at the same time usually has a negative impact on the environment. The most important problem arising in this context is to find an optimal, or at least an appropriate path between these "two evils".

In Russia and many transitional countries large investment projects related to extraction and use of natural resources, are the subject of governmental consideration and need a permit in order to be implemented. Quality of growth indicators can provide the information tools for this purpose. They are to be the necessary components of integrated ecological-economic approach to assess social consequences of different development strategies

2. ECO-INTENSITY

Several quality of growth indicators can be considered as the criteria in the investment decisions.
We propose to use the well known indicators from NAMEA, the European system of environmental accounting (De Haan, 1996).

- eco-productivity:

$$Ep = {y_j}/{e_j^p}$$

- eco-intensity

$$Ei = {e_j^p}/{y_j}$$

where y_j is the added value produced by a sector/enterprise (*j*), e_j^p – the amount of negative impact on the environment of a type (p) from a sector /enterprise (*j*).

We include in our system of criteria three eco-intensity indicators: eco-intensity of atmosphere emissions, eco-intensity of discharge into water, eco-intensity of waste production and total eco-intensity indicator. The total eco-intensity indicator $E_{из}$ for investment project is defined by the formula:

$$E_{из} = (E_a+E_o+E_в)/Y,$$

where E_a –is the quantity of atmosphere emissions;
E_o – quantity of wastes;
$E_в$ – polluted water discharge;
Y – value added provided by the project

Eco-intensity indicators are very important. However these indicators do not capture the effect of accumulation polluting substances into a stock in the natural environment.

3. THE MODEL: POLLUTING SUBSTANCE ACCUMULATES TO A STOCK IN THE NATURAL ENVIRONMENT

Follow the paper by Baumgartner et al (2002) we introduce the per unit social cost of pollution in each period of time and denote it by $d > 0$. It includes "all direct and indirect costs of society incur due to the danger from pollution" in one time period. (Baumgartner et al, 2002, p.7). We do not discuss here how we can calculate this cost. Anyway, it might be far from the environmental tax and the polluter's environmental costs. In practice, usually $g \ll d$, because many negative impacts are not taken into account.

We consider a project of investment in a new enterprise (or to modernization of an existing enterprise). The outcomes of this project will be produced goods and, at the same time, a negative effects on the environment. Emissions can accumulate to a stock pollution. Below, by "firm" we mean the business actor which makes the investment decision.

Now we can introduce the model.

The Model

M1. New investment results in the production of a consumption good at a constant level q which is sold by price p in every year i, $i = 1,...n$. We call n the lifetime of the project, $n > 1$.
M2. The production cost is $c > 0$ per unit of consumption good and it does not depend on time.
M3. The present value of the fixed cost of investment is $f > 0$ and there is no deterioration of the production capital.
M4. An emission from production is $e > 0$ per unit of consumption good.
M5. The negative impact of pollution on social welfare is proportional to the quantity of the accumulated stock. It is estimated as $d > 0$ per unit of pollution stock in each year.
M6. The initial pollution stock is equal to zero.
M7. The discount rate is $r > 0$ in each year.
M8. The pollutant accumulates to a stock in the natural environment. A constant fraction of the accumulated pollution stock naturally degrades; the natural degradation rate is $\delta \in (0,1)$.
M9. The total environmental cost of the producer, including the environmental tax, is $g > 0$ per unit of emissions

4. FIRM'S PROFIT AND SOCIAL BENEFIT

The net present value of the firm's profit we denote by $\pi(\mathrm{n})$, where n is the firm's time horizon. It is easy to show that:

$$\pi(n) = \sum_{i=1}^{n} \frac{q(p-c-ge)}{(1+r)^i} - f \qquad (1)$$

The inequality $\pi(\mathrm{n}) > 0)$ is a necessary condition for the positive investment decision.

Now we try to estimate the benefit for society from this project. Denote this benefit by *B(n)*. Simple calculation shows that:

$$B(n) = q(p-c) \cdot a(n,r) - dqe\sum_{t=1}^{n} \frac{1-(1-\delta)^t}{\delta(1+r)^t} - f\,, \qquad (2)$$

where $a(n,r) = \sum_{t=1}^{n} \frac{1}{(1+r)^t}$.

We can also consider the case where there is no natural degradation of the polluting substance in the environment, i.e. $\delta = 0$. In this case the amount of the pollutant stock in the environment at the end of time period t and the social cost are equal to (see also (Baumgartner et al, 2002))

$$S_t = qet \quad \text{and} \quad D_t = dS_t = dqet$$

This implies that the social benefit for $\delta = 0$ may be represented by the formula:

$$B(n) = q(p-c)\sum_{t=1}^{n} \frac{1}{(1+r)^t} - dqe\sum_{t=1}^{n} \frac{t}{(1+r)^t} - f =$$

$$= q(p-c)\frac{1}{r}[1-\frac{1}{(1+r)^n}] - dqe\sum_{t=1}^{n} \frac{t}{(1+r)^t} - f \qquad (3)$$

5. THE TIME BOUNDARY OF INVESTMENT EXPEDIENCY

Obviously, $\pi(\mathrm{n})$ is an increasing function with respect to *n.* One can see that the longer is the time horizon, the more likely is the considered project to be launched. On other hand, the function representing the social benefit *B(n)* is not monotonic in general (Glazyrina and Potravny, 2005). It monotonically increases for all n if $(\mathrm{p-c})\delta \geq \mathrm{de}$. But if $(\mathrm{p-c})\delta < \mathrm{de}$ it increases while $n < \beta$,

$$\beta = \frac{\ln(1+\frac{\delta(\mathrm{p-c})}{\mathrm{de}})}{\ln(1-\delta)} - 1 \cdot \qquad (4)$$

If $n > \beta$ and $(\mathrm{p-c})\delta < \mathrm{de}$ the function $\pi(\mathrm{n})$ is decreasing.

So if $n > \beta$ the society as a whole is not interested in a continuation of this project. If the project is implemented by private business and the company has to pay the total social cost, the company may also not be very interested in this investment. We call *β,* defined by (4*), the time boundary of investment expediency.* It might be also considered as a time indicator of "uneconomic growth" on the micro-level (Daly and Farley, 2003).

However, as we indicated above, the polluting company in Russia must pay an environmental tax proportional to the amount of emissions. Therefore it does not pay the total social cost and its profit is determined by formula (1). So the company is not sensitive to the boundary of investment expediency, which is important for society. In other words, the existing procedure of the polluter pays principle (PPP) implementation (i.e. payment proportional to the amount of emissions) generates a potential conflict between private business and society as a whole. While $n > \beta$ the social benefit from the project is decreasing and the interests of society require the project not to proceed. At the same time the private company is interested in its continuation. We can conclude that economic imperfections (Munasinghe and Cruz, 1995; Munasinghe, 1999) may influence the quality of growth in the context of sustainability (Panayotou, 1995)

Our model allows us to make a modeling simulation in order to determine the time boundary of investment expediency (the "point of potential conflict") for specific projects depending on the main quantitative parameters (*e, d, f, r, q* and $\delta \in (0,1)$). We show some results of such modeling in the Figures 1-2.

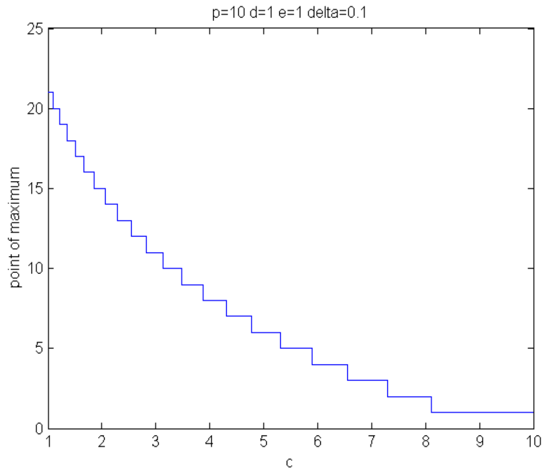

Fig 1. Dynamics of a "point of potential conflict" in dependence on production cost *c.* Market price *p* of produced commodity, emissions *e*, negative impact of pollution on social welfare $d > 0$ per unit of pollution stock and assimilation coefficient *δ* are fixed. Point of maximum equals β. (Glazyrina and Potravny, 2005).

Figures 1 shows the case when polluting substance accumulates to a stock in the natural environment and the natural degradation rate of this pollutant is $\delta \in (0,1)$. One can see that even when the project is profitable from the commercial point of view ($c < 0.5p$) it may be not desirable for society if its lifetime is more that 5-6 years. In this situation there is a real danger of the a conflict of interests.

In Figure 2 one can see the case when there is no natural degradation of the pollutant in the environment. A conflict of interests may arise within the time period 4-10 years even if the negative impact of pollution on social welfare *d* per unit of pollution stock is less than $0.1p$, i.e. it is comparatively small.

We see, that even in an ideal case, when the social costs are totally estimated and taken into account, there is a danger of a potential conflict between the interests of society and those of private business. The crucial circumstances for this conflict is the conventional implementation of the polluter pays principle (PPP), when an environmental tax exists in the form of a payment proportional to the amount of emissions but does not depend on the lifetime of the pollutant.

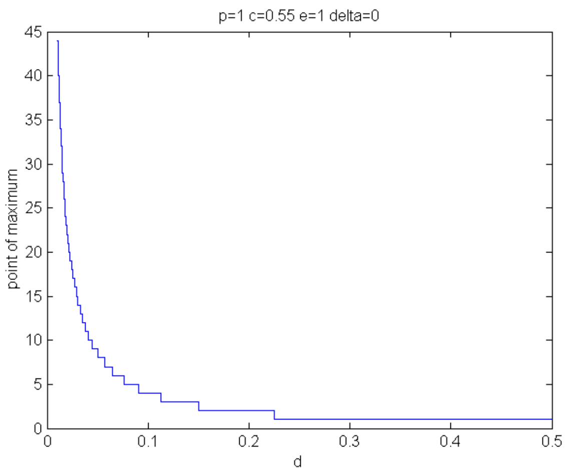

Fig.2. Dynamics of a "point of potential conflict" in dependence on negative impact of pollution on social welfare d per unit of pollution stock. There is no natural degradation of the polluting substance in the environment, i.e. $\delta = 0$. Market price p of produced commodity, production cost c, emissions c, assimilation coefficient δ and negative impact of pollution on social welfare $d > 0$ per unit of pollution stock are fixed. (Glazyrina and Potravny, 2005)

In our simulation modeling we have assumed that the total environmental cost of the producer, including the environmental tax, is (per unit of emission) equal to the negative impact of the pollution on social welfare (per unit of pollution stock), i.e. $g = d$. One can see that even in this optimistic case there is an unavoidable potential for conflict if $(\mathrm{p} - \mathrm{c})\delta < \mathrm{de}$ and $n < \beta$, where β is he point of maximum for the function B(n), defined by formula (4)

7."CORRECTED" ENVIRONMENTAL TAX

The analysis presented in the previous sections demonstrates that a "simple decision" in PPP implementation (when the environmental tax is determined proportional to the amount of emissions and does not depend on the lifetime of a project) is not adequate to the real negative impact if the pollutant accumulates to a stock in the environment. Now we shall try to find "a corrected" amount for the environmental tax which covers the negative effect on social welfare. Let us denote by h the amount of the environmental tax for the investment project described by the model in Section 3. We obtained that the present (discounted) value of the total negative impact on social welfare in the monetary form is equal to:

$$D(n) = dqe\sum_{t=1}^{n} \frac{1-(1-\delta)^t}{\delta(1+r)^t}$$

(see formula (2)). On the other hand, h must satisfy the equation:

$$D(n) = h\sum_{t=1}^{n} \frac{1}{(1+r)^t}$$

It is obvious that h depends on the lifetime of the project n and this is a very important factor. So we suppose that $h = h(n)$ and

$$h(n) = de\frac{\sum_{t=1}^{n} \frac{1-(1-\delta)^t}{\delta(1+r)^t}}{\sum_{t=1}^{n} \frac{1}{(1+r)^t}}$$

One can see that $h(n)$ is a monotonically increasing function with respect to n (Glazyrina and Potravny,2005). So the next conclusion is that the longer is the project lifetime, the higher needs to be the environmental tax.

It is essential that the "correct size" of the environmental tax $h(n)$ should depend on a discount rate and on the rate of natural degradation of the polluting substance δ. To be accurate we should write $h = h(n,r,\delta)$. We can see (Glazyrina and Potravny, 2005), that $h(n,r,\delta)$ is a decreasing function with respect to r and δ. This means, that:

(1) the larger is the rate of discount, the lower is the environmental tax;
(2) the lower is the rate of natural degradation of the pollutant, the higher is the environmental tax.

8. MICROECONOMIC QUALITY OF GROWTH INDICATORS

The model analysis allows us to obtain the negative impact D(·) of pollution on social welfare in monetary terms. We consider it in three cases:

1. Polluting substance naturally degrades in a one period of time and does not influence the environment in the next period:

$$D = \sum_{i=1}^{n} \frac{qde}{(1+r)^i}$$

2. The pollutant accumulates to a stock in the natural environment. It naturally degrades; the degradation rate is:

$$D(\delta) = dqe \cdot \sum_{t=1}^{n} \frac{1-(1-\delta)^t}{\delta(1+r)^t}$$

3. The natural degradation rate of pollutant is close to zero:

$$D(0) = dqe \cdot \sum_{t=1}^{n} \frac{t}{(1+r)^t}$$

The total production of consumption good within the project in monetary term is

$$Y = \sum_{i=1}^{n} \frac{qp}{(1+r)^i}$$

We propose the following environmental quality of growth indicators on the micro-level (i.e. connected with specific project) for each three cases considered above:

- $MIn = D/Y$, if the polluting substance naturally degrades in a one period of time;
- $MIn(\delta) = D(\delta)/Y$, if there is natural degradation of the polluting substance, and
- $MIn(0) = D(0)/Y$, in the case without natural degradation of the polluting substance.

These indicators express the share of the interests on ecological debt (from a considered project or enterprise) in the total production.

If the pollutant accumulates to a stock the environmental quality of growth indicators $MIn(\delta)$ and $MIn(\delta)$ depend on the lifetime of the project. Both expressions $MIn(\delta)$ and $MIn(\delta)$ are increasing functions with respect to n. We provide the analytic proof of this proposition.

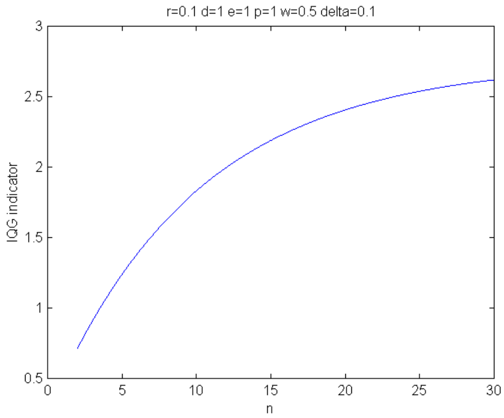

Fig. 3. Dependence of indicator $MIn(\delta)$ on the project lifetime, δ= 0.1 (Glazyrina and Potravny,2005)

There exist the upper bounds of $MIn(\delta)$ and $MIn(0)$ for all n. This result is also analytically proved in (Glazyrina and Potravny,2005). We obtain the following:

$$\lim_{n\to\infty} MIn(\delta) = ped\frac{1+r}{r+\delta},$$

$$\lim_{n\to\infty} MIn(0) = ped\frac{1+r}{r},$$

With this model we can make a modeling simulation in order to calculate $MIn(\delta)$ and $MIn(0)$. Some results are presented on the Figures 3-5.

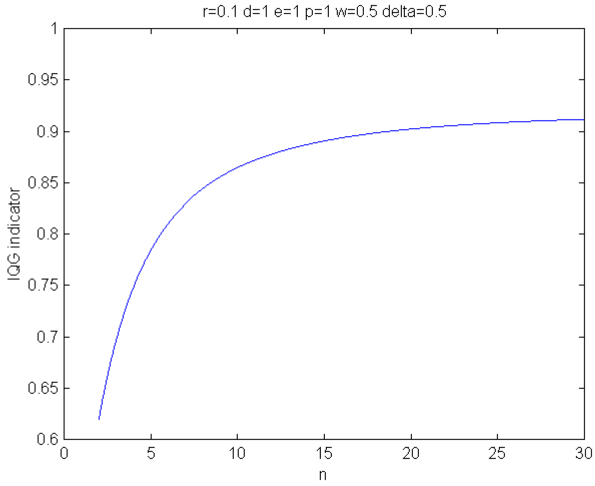

Fig.4. Dependence of indicator $MIn(\delta)$ on the project lifetime, δ= 0.5. (Glazyrina and Potravny,2005)

Our model analysis shows that the characteristics of natural degradation of a pollutant and time horizon of emissions are very important in the context of the quality of economic growth.

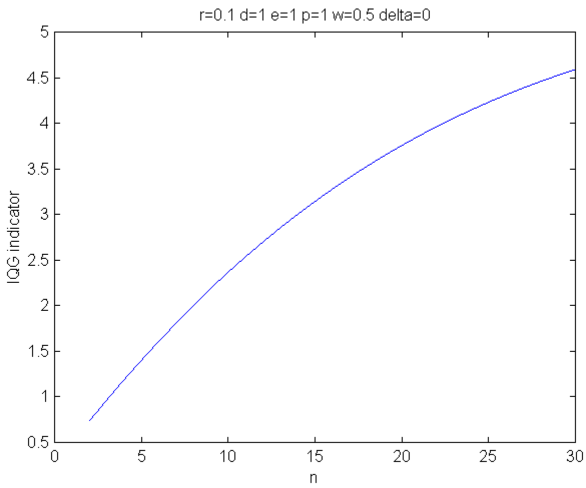

Fig. 5. Indicator $MIn(0)$ in the case of no natural degradation of the polluting substance (Glazyrina and Potravny,2005).

The simple analytic form of proposed indicators allows to make the forecast about long-term consequences of investment initiatives based on model calculations. It is substantial in decision-making procedures when there exist a problem of choice between several alternatives of development

9. CONCLUSION

The notion "interests on ecological debt" has been introduced by E.Ryumina (Ryumina, 2000, Glazyrina, 1998) . Interests on ecological debt consist of:

- a share of national income which society has to use for restoration of environment, health care because of pollution and deterioration of environment;

- a difference in national income which society cannot obtain because of deterioration of natural resources and degradation of ecosystem services.

So we can consider *D, D(δ), D(0)* as a total discounted (with a rate *r*) input into interests on ecological debt from a specific production process. The indicators *MIn(δ)* and *MIn(0)* therefore present the input into interests on ecological debt per unit of production. They reflect the increasing harm from polluting substances which accumulate to a stock in the natural environment. If we include the indicators *MIn(δ)* and *MIn(0)* into the system of criteria in addition to "indicators of direct impact" like eco-intensity, we obtain more comprehensive information for decision-making.

This is important, because an adequate evaluation of social costs is still a very difficult problem. Environmental legislation in transitional countries usually underestimates these costs, so the way to "corrected" environmental taxes seems to be far off in practice. While the danger of potential conflict exists, it means that society needs alternative, non monetary arguments to advocate its long-term interests (Söderbaum, 2000, 2004). It should be noted that this conflict may arise in a country with conventional implementation of PPP whether it is transitional or developed. But in transitional countries, under conditions of limited democracy and weakness of public institutions we can expect the most negative consequences (Voinov et al, 1999).

10. ACKNOWLEDGEMENTS

The author would like to thank Prof. S. Baumgartner, M.Faber, G.Liesegang, J.Proops, P. Söderbaum, S.Vinnichenko. Support from Dutch-Russian program NWO-RFBR (Project "Quality of growth indicators for economies in transition") and from Russian Humanitarian Scientific Foundation (project № 04 – 02 – 00182a) is also gratefully acknowledged.

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