Separating and Pooling Incentive Mechanisms of Ecological Regulation: The Cases of Developed and Developing Countries *

Vladimir D. Matveenko[1] **and Alexey V. Korolev**[2]

[1] *National Research University Higher School of Economics*
16 Soyuza Pechatnikov street, Saint-Petersburg 190121, Russia
E-mail: vmatveenko@hse.ru
[2] *National Research University Higher School of Economics*
16 Soyuza Pechatnikov street, Saint-Petersburg 190121, Russia
E-mail: danitschi@mail.ru

Abstract A model of contract theory is studied, where the objective functions of a regulation body and firms of two types involve ecological variables. It is shown that the way of working of the regulation mechanism (unifying or pooling) depends on both political conditions (regulators of what type set mechanism and contracts), and on economical conditions (distinction between "dirty" and "green" firms in efficiency and a degree of their spreading in the economy). Under small difference in a parameter values characterizing the types of firms it appears that if (what seems to be typical for many developing and transition economies) a use of "dirty" technologies raises the rentability of firms and the part of "dirty" firms in economy is great then the pooling (i.e., in some sense, non-market) contract mechanism is chosen more often. Under conditions which seem to be typical for developed countries (relatively more efficient "green" firms), a choice of separating (in a more degree market) mechanism can be expected.

Keywords: Menu of contracts, pooling contract, ecological regulation, developed and developing countries.

AMS Classification: 91A, 91B, 94A, 93C, 49B.
JEL Classification: Q57, C72, C73, K22, P48.

1. Preface

A part of the global problem of stabilization of environment is connected with ensuring of effective ecological regulation in transition and developing economies, where a considerable part of the world industrial production is concentrated. In 2004 the share of seven main "emerging" economies (E7: China, India, Brazil, Russia, Mexico, Indonesia, Turkey) in global carbonic dioxide emission was 32.1%, and according to forecasts it will increase up to 42.6% by 2025 year and up to 49% by 2050 (Hawksworth, 2006). According to (Davis and Caldeira, 2010), the main commodities exporters in the world whose production is related with the atmosphere pollution in the present time are China, Russia, Middle East countries, South Africa countries, Ukraine, India, Malaise, Thailand, Thai-vane, Venezuela.

Researchers usually explain modest results of economic policy in Russia and other transitional economies, and, in particular, of ecological policy, by "inherited"

* The research was accomplished in frame of the Program of Fundamental Research of the National Research University Higher School of Economics in 2011

manners of behavior and institutions, as well as by conflicts between new formal and old non-formal institutions. However, there is another possibility: "new" economies possess purely economic peculiarities that lead to serious differences in work of those institutional mechanisms which showed themselves quite good in developed countries.

If in industrial countries the same firms that inflict the least damage to environment are in the same time the most effective in the sense of rentability, then in many developing and transition economies, on the contrary, many firms can obtain a large economic gain by inflicting a direct or indirect pollution.

Laffont (Laffont, 2000) investigated a model of ecological regulation that rather exactly corresponds to economic situation in industrial countries. In this model firms-monopolists are considered which possess cost function as follows:

$$C(\theta, d) = \theta(K - d),$$

where $K > 0$ is some common for all the firms constant, $\theta > 0$ is a characteristic of costs that is a private information of a firm (the type of firm), $d > 0$ is a level of pollution allowed for firms of that type (chosen by the firm from a menu of contracts proposed by the regulator or definitely established by the regulator). It follows from the formula that if there are two types of firms, $\underline{\theta} < \bar{\theta}$, under a possibility to increase the level of pollution d the firm of type $\underline{\theta}$ (it may be interpreted as "green") receives a smaller cost decrease than the firm of type $\bar{\theta}$ ("dirty").

The regulating body possessing an information about costs of the types and about their share (frequency) in the economy but possessing no information about a type of a concrete firm assigns either a pooling contract or a menu of contracts $M = \{(\underline{t}, \underline{d}), (\bar{t}, \bar{d})\}$ (where $\underline{t}, \bar{t}$ are the sizes of transfers, $\underline{d}, \bar{d}$ are allowed pollution levels) from which a firm chooses an optimal for itself contract. In the Laffont model the firm of type $\underline{\theta}$ is economic efficient and receives an information rent; the origin of the latter is related to a possibility for the firm to "pretend" to belong to other type.

Three types of regulators were considered, they differ by objective functions: a social maximizer, an interested majority and an disinterested majority; the interested majority is found to be the most effective regulator from the point of view of decreasing the pollution levels .

Matveenko (Matveenko, 2010) has proposed a more general model with a cost function:

$$C(\theta, d) = \kappa(\theta) - \theta d, \tag{1}$$

where $\kappa(\theta) > 0$. If there are two type of firms, $\underline{\theta} < \bar{\theta}$ then it is natural to consider as *an index of relative economical efficiency* the value

$$\tilde{K} = \frac{\kappa(\bar{\theta}) - \kappa(\underline{\theta})}{\Delta\theta},$$

where $\Delta\theta = \bar{\theta} - \underline{\theta}$. The relative efficiency of a "dirty" firm may increase both by increasing of differential $\Delta\theta$ and by decreasing the value $\kappa(\bar{\theta})$, that may be interpreted as investments in quality of product (e.g., the costs of R&D and modernization). Negative values of $\widetilde{K}$ are permitted. For "small" values of $\tilde{K}$ the firm of type $\bar{\theta}$ ("dirty") proves to be a a rent receiver, and for "high" values of $\tilde{K}$ the type $\underline{\theta}$ ("green") does. For "intermediate" values of $\tilde{K}$, no type of firms can capture a rent.

The notions of "small" and "high" $\tilde{K}$ are defined more precisely in dependence on which type regulator is in power and forms the menu of contracts.

In a case typical for developing and transitional economies, when the share (frequency) of firms able to receive an advantage from pollution is relatively large and these firms are relatively effective ($\tilde{K}$ is "small"), the interested sides being in power allow an extremely high pollution level for firms of type $\underline{\theta}$; moreover, not a separating mechanism with a free choice from a menu of contracts is used but a pooling mechanism i.e. an assignment of a unique common contract. That implies (outside the frame of the model) a more high degree of the state intervention into economy and more narrow relations between the regulator and the firms which may lead to a higher degree of corruption. All this takes place under the same "standard" institutions which are relatively successful in solving the ecological regulation problem in developed countries where economic condition are different ($\tilde{K}$ is "high").

In this paper the study of the model (Matveenko, 2010) is continued and the main attention is paid to the question: what type of the mechanism (pooling or separating) will be chosen under different political and economical conditions? The research is done under an assumption of small $\Delta\theta$. Two situations are under consideration:

(a) the type of mechanism is defined by the society whilst the decision, in frame of this mechanism, is made by a regulator (interested or disinterested sides),

(b) both the type of the mechanism and the decision about pollution levels are defined by a regulator.

We show that under conditions which seem to be typical for developing and transition economies ("dirty" firms are relatively effective and their share in the economy is relatively high), one ought in more degree expect a pooling (i.e. non-market) mechanism assignment.

In section 2 a description of the model is given. In section 3 the equilibrium pollution levels in different cases are found. In section 4 a comparison of the separating and the pooling mechanisms is done. Section 5 concludes.

2. The basic model

Let a fulfillment of a project having social value S be realized by a firm which carries pure costs (1), where $\kappa(.) > 0$, d is a pollution level allowed to the firm, θ is a characteristic of costs which is a private information of the firm (the type of the firm), and θ takes two values: $\underline{\theta}$ with probability ν and $\bar{\theta}$ with probability $(1-\nu)$, and $\underline{\theta} < \bar{\theta}$.

Denote through t a pure transfer received by the firm. For $t > 0$ it is actually a transfer, and for $t < 0$ the magnitude $(-t)$ represents a tax paid by the firm. The rent received by the firm is

$$U = t - C(\theta, d).$$

We admit a possibility of $C(\theta, d) < 0$, i.e. of receiving a pure profit by the firm (it may be supposed, in sake of simplicity, that the pure profit arises at the expense of an export activity, i.e. it does not lie down on the shoulders of the consumers). The firm will execute the project if $U \geq 0$. In contract theory this condition is known as *individual rationality, IR.*

A social evaluation of a pollution harm is $V(d)$ where $V'(.) > 0$, $V''(.) > 0$. The welfare of the consumers is equal to

$$S - V(d) - (1+\lambda)t.$$

In (Laffont, 2000) the parameter λ is interpreted as social costs per unit of transfer. We, admitting also a possibility of a tax, tract $1+\lambda$ broader as a rate of returns which characterizes the advantage of using in another projects the means which the society loses in form of transfer or gains in form of tax from firm. We assume that $\lambda > 0$ is constant; the passage to an assumption that λ is a random value doesn't change the character of results.

The social welfare consist of the consumers' welfare and the rent:

$$S - V(d) - (1+\lambda)t + U = S - V(d) - (1+\lambda)(\kappa(\theta) - \theta d) - \lambda U.$$

Under a perfect information the social welfare maximization results in zero rent, and for firms of types $\underline{\theta}$ and $\bar{\theta}$, correspondingly, the pollution levels $\underline{d}^*$, $\bar{d}^*$ are assigned such that

$$V'(\underline{d}^*) = (1+\lambda)\underline{\theta}, \quad (2)$$
$$V'(\bar{d}^*) = (1+\lambda)\bar{\theta}.$$

Under an imperfect information, when the type of firms is unknown to the regulator, if the *separating regulation mechanism* acts the regulator proposes to a firm a menu of contracts

$$M = (\underline{t}, \underline{d}), (\bar{t}, \bar{d}),$$

satisfying (1) the conditions of *incentives compatibility, IC*, the sense of which is that no firm can receive a gain by "pretending" to be a firm of another type:

$$\underline{t} - C(\underline{\theta}, \underline{d}) \geq \bar{t} - C(\underline{\theta}, \bar{d}), \quad (3)$$

$$\bar{t} - C(\bar{\theta}, \bar{d}) \geq \underline{t} - C(\bar{\theta}, \underline{d}), \quad (4)$$

and (2) conditions of IR which have been already mentioned:

$$\underline{t} - C(\underline{\theta}, \underline{d}) \geq 0, \quad (5)$$

$$\bar{t} - C(\bar{\theta}, \bar{d}) \geq 0. \quad (6)$$

Besides, the menu of contracts M maximizes the regulator's objective function, in which transfers enter with a minus sign, i.e. the regulator is interested in cutting down transfers. In (Matveenko, 2010) it is is proven that the optimal menu of contracts satisfying the conditions IC and IR possesses the following properties:

1) a necessary and sufficient condition of receiving a rent by a firm of type $\underline{\theta}$ is the inequality $\tilde{K} > \bar{d}$ (the case of "*large*" $\tilde{K}$);

2) a necessary and sufficient condition of receiving a rent by a firm of type $\bar{\theta}$ is the inequality $\tilde{K} < \underline{d}$ (the case of "*small*" $\tilde{K}$);

3) if $\underline{d} \leq \tilde{K} \leq \bar{d}$ (the case of "*intermediate*" $\tilde{K}$) then no type of firms may obtain rent.

In the case of "large" $\tilde{K}$ a firm of type $\bar{\theta}$ receives no rent, and the rent received by the firm of type $\underline{\theta}$ is equal to

$$\underline{U} = \bar{t} - C(\underline{\theta}, \bar{d}) = \Delta\theta(\tilde{K} - \bar{d}).$$

In the case of "small" $\tilde{K}$ a firm of type $\underline{\theta}$ receives no rent, and a firm of type $\bar{\theta}$ receives the rent

$$\bar{U} = \underline{t} - C(\bar{\theta}, \underline{d}) = \Delta\theta(\underline{d} - \tilde{K}).$$

Thus, the rent depends on the pollution level of another (receiving no rent) type of firm, but the dependence under a "large" $\tilde{K}$ is negative and under a "small" $\tilde{K}$ is positive. This fact, essentially, defines the difference in pollution levels which the interested sides being in power set under different economic conditions.

Let us assume that the interested sides are in power with probability p, and the disinterested sides are in power with probability q, and that each of the sides being in power receives a share $\alpha^* > 1/2$ of the consumers welfare. An analogous assumption in (Laffont, 2000) is motivated by supposing that, under conditions of democracy, a majority of population comes to power and the majority is always α^*. Referring the types of the regulator we use in the paper terms (Laffont, 2000): *disinterested majority*, or *majority-1* when we speak about the disinterested sides in power, and *interested majority*, or *majority-2* when we speak about the interested sides in power. For us these are only the terms to distinguish regulators' types.

3. Decisions of the regulator

In this section we indicate equilibrium pollution levels being included into the menu of contracts (in case, when the regulator uses a separating mechanism) or being set (if the regulator uses a pooling mechanism). The knowledge of these pollution levels will be needed in Section 4 for a comparison of separating and unifying mechanisms.

3.1. Separating mechanism

Disinterested majority makes decision Let the firm of type $\overline{\theta}$ receive a rent (the case of "small" $\tilde{K}$). The objective function of the majority-1 takes the form

$$\alpha^* E[S - V(d) - (1+\lambda)t] = \alpha^*[\nu(S - V(\underline{d}) - (1+\lambda)(\kappa(\underline{\theta}) - \underline{\theta}\underline{d}))+$$
$$+(1-\nu)(S - V(\bar{d}) - (1+\lambda)(-\bar{\theta}\bar{d} + \kappa(\underline{\theta}) + \Delta\theta\underline{d}))]. \quad (7)$$

Maximizing this function the majority-1 includes to the menu of contracts the pollution level $\overline{d}^*$ and the level $\underline{d}_1$ satisfying the equation

$$V'(\underline{d}_1) = (1+\lambda)\underline{\theta} - (1+\lambda)\frac{1-\nu}{\nu}\Delta\theta. \quad (8)$$

This menu of contracts is feasible only under $\tilde{K} < \bar{d}_1$. The latter inequality is the condition defining in that case the notion of "small" $\tilde{K}$.

Let firm of type $\underline{\theta}$ receive a rent (the case of "large" $\tilde{K}$). Analogously, the majority-1 inserts into the menu pollution levels $\underline{d}^*$ and $\bar{d}_1$, where

$$V'(\bar{d}_1) = (1+\lambda)\bar{\theta} + (1+\lambda)\frac{\nu}{1-\nu}\Delta\theta. \quad (9)$$

For the feasibilty of the menu of contracts the inequality $\tilde{K} > \bar{d}_1$ has to be fulfilled (this is an identifer of the "large" $\widetilde{K}$).

In case, when no type of firm receives a rent (the case of "intermediate" $\tilde{K}$), under $\underline{d}^* \le \tilde{K} \le \bar{d}^*$ the menu of contracts with pollution levels $\underline{d}^*$, $\bar{d}^*$ is optimal. Under $\underline{d}^* \le \tilde{K} \le \bar{d}_1$ the menu of contracts includes pollution levels $\underline{d} = \underline{d}^*$, $\bar{d} = \tilde{K}$. Under $\underline{d}_1 \le \tilde{K} \le \underline{d}^*$ the pollution levels $\underline{d} = \tilde{K}$, $\bar{d} = \bar{d}^*$ are used.

Interested majority makes decision If the firm of type $\overline{\theta}$ receives a rent (the case of "small" $\tilde{K}$) then the objective function of the majority-2 has the form:

$$\alpha^*\nu[S - V(\underline{d}) - (1+\lambda)(\kappa(\underline{\theta} - \underline{\theta}\underline{d}))+$$
$$+(1-\nu)(S - V(\bar{d}) - (1+\lambda)(\kappa(\overline{\theta}) - \bar{\theta}\bar{d}) - (1+\lambda-1/\alpha^*)(\kappa(\underline{\theta}) - \kappa(\overline{\theta}) + \Delta\theta\underline{d}))]. \quad (10)$$

Maximization results in the pollution level $\overline{d}^*$ and the level $\underline{d}_2$ satisfying the following equation

$$V'(\underline{d}_2) = (1+\lambda)\underline{\theta} - \left(1+\lambda - \frac{1}{\alpha^*}\right)\frac{1-\nu}{\nu}\Delta\theta. \quad (11)$$

This menu of contracts is feasible only if $\widetilde{K} < \underline{d}_2$. One more feasibility condition is the restriction on model parameters:

$$1+\lambda > \frac{1-\nu}{\alpha^*}$$

(this inequality is equivalent to $\underline{d}_2 < \overline{d}^*$).

If the firm of type $\underline{\theta}$ receives the rent (the case of "large" $\widetilde{K}$) then, analogously, the majority-2 chooses the pollution level $\underline{d}^*$ and the level $\overline{d}_2$ such that

$$V'(\overline{d}_2) = (1+\lambda)\underline{\theta} - \left(1+\lambda - \frac{1}{\alpha^*}\right)\frac{\nu}{1-\nu}\Delta\theta. \quad (12)$$

For feasibility the inequality $\widetilde{K} > \overline{d_2}$ is required. Besides, the following condition on the parameters has to be fulfilled:

$$1+\lambda > \frac{\nu}{\alpha^*}$$

(this is equivalent to $\underline{d}^* < \overline{d}_2$).

If no type of firms receives rent (the case of "intermediate" $\widetilde{K}$) and

$$1+\lambda > \frac{1}{\alpha^*},$$

then for $\underline{d}^* \leq \widetilde{K} \leq \overline{d}^*$ the menu of contracts with pollution levels $\underline{d}^*$, $\overline{d}^*$ is optimal; under $\overline{d}^* < \widetilde{K} \leq \overline{d}_2$ the menu of contracts includes pollution levels $\underline{d} = \underline{d}^*$, $\overline{d} = \widetilde{K}$; and under $\underline{d}_2 \leq \widetilde{K} < \underline{d}^*$ the pollution levels $\underline{d} = \widetilde{K}$, $\overline{d} = \overline{d}^*$ will be used.

If the value $1+\lambda-1/\alpha^*$ is negative but is not too large by its absolute value, so that

$$\underline{d}^* < \underline{d}_2 < \overline{d}_2 < \overline{d}^*,$$

then under $\underline{d}_2 \leq \widetilde{K} \leq \overline{d}_2$ the regulator includes into the menu of contracts pollution levels $\underline{d}^*$ $\overline{d}^*$.

3.2. Unifying mechanism

Under definite conditions (see Section 4) it is advantageous for regulator to use a pooling mechanism instead of a separating menu of contracts. This may serve an explanation of comparatively low spreading of market regulation mechanisms in developing and transitional economies in comparison with developed countries.

Under a *pooling regulation mechanism* the regulator proposes only one (common for all firms) contract (t, d). Conditions IC now have no sense, but there ought to hold the conditions IR and, thus,

$$t = \max\{C(\underline{\theta}, d), C(\overline{\theta}, d)\}.$$

The rent $U = t - C(\theta, d)$ will be received by that type of firm for which costs are less. Under $\widetilde{K} < d$ the firm of type $\overline{\theta}$ receives a rent, and under $\widetilde{K} > d$ the firm of type $\underline{\theta}$ does, and, besides, in both cases the rent is equal to $|\widetilde{K} - d|\Delta\theta$. The rent is absent in a single case when $\widetilde{K} = d$.

Disinterested majority makes decision In case of "small" $\widetilde{K}$ when a rent is received by the firm of type $\overline{\theta}$ the majority-1 maximizes the function

$$\alpha^*[S - V(d) - (1+\lambda)E(\kappa(\theta) - \theta d) - (1-\nu)(1+\lambda)(\kappa(\underline{\theta}) - \kappa(\overline{\theta}) + \Delta\theta d)], \quad (13)$$

and solution is $d_1^s = \underline{d}^*$. A "smallness" $\widetilde{K}$ is realized as $\widetilde{K} < \underline{d}^*$.

In case of "large" $\widetilde{K}$ when the firm of type $\underline{\theta}$ receives a rent the majority-1 maximizes the function

$$\alpha^*[S - V(d) - (1+\lambda)E(\kappa(\theta) - \theta d) - \nu(1+\lambda)(\kappa(\overline{\theta}) - \kappa(\underline{\theta}) + \Delta\theta d)],$$

and solution is $d_1^h = \overline{d}^*$. "Large" $\widetilde{K}$ means $\widetilde{K} > \overline{d}^*$.

Disinterested majority makes decision In case of "small" $\widetilde{K}$ when the firm of type $\overline{\theta}$ receives a rent the majority-2 maximizes the function

$$\alpha^*[S - V(d) - (1+\lambda)E(\kappa(\theta) - \theta d) - (1-\nu)\left(1 + \lambda - \frac{1}{\alpha^*}\right)(\kappa(\underline{\theta}) - \kappa(\overline{\theta}) + \Delta\theta d)] \quad (14)$$

and sets such pollution level d_2^s that

$$V'(d_2^s) = (1+\lambda)[\nu\underline{\theta} + (1-\nu)\overline{\theta}] - (1-\nu)\left(1 + \lambda - \frac{1}{\alpha^*}\right)\triangle\theta] = (1+\lambda)\underline{\theta} + \frac{1}{\alpha^*}(1-\nu)\triangle\theta. \quad (15)$$

"Small" $\widetilde{K}$ means $\widetilde{K} < d_2^s$.

In case of "large" $\widetilde{K}$ when the firm of type $\underline{\theta}$ receives the rent the majority-2 maximizes the function

$$\alpha^*[S - V(d) - (1+\lambda)E(\kappa(\theta) - \theta d) - \nu\left(1 + \lambda - \frac{1}{\alpha^*}\right)(\kappa(\overline{\theta}) - \kappa(\underline{\theta}) - \Delta\theta d)],$$

and sets the pollution level d_2^h such that

$$V'(d_2^h) = (1+\lambda)[\nu\underline{\theta} + (1-\nu)\overline{\theta}] + \nu\left(1 + \lambda - \frac{1}{\alpha^*}\right)\triangle\theta] = (1+\lambda)\overline{\theta} - \frac{1}{\alpha^*}\nu\triangle\theta.$$

"Large" $\widetilde{K}$ means $\widetilde{K} > d_2^h$.

In the case of "small" $\widetilde{K}$ the least pollution level is set by the majority-1, and the greatest by the majority-2. This comparison is correct under $\widetilde{K} < \underline{d}^*$. In this case the pollution levels are such that

$$\underline{d}^* = d_1^s < d_2^s.$$

In contrary, in the case of "large" $\widetilde{K}$ the least pollution level is set by the majority-2, and the greatest by the majority-1. This comparison is correct under $\widetilde{K} > \overline{d}^*$. In this case pollution levels are such that

$$d_2^h < d_1^h = \overline{d}^*.$$

As far as the derivative $V'(.)$ must be positive we must put some additional restrictions on model parameters:

$$(1+\lambda)\overline{\theta} > \frac{1}{\alpha^*}\nu \triangle \theta,$$

$$\underline{\theta} > \frac{1-\nu}{\nu} \triangle \theta,$$

$$(1+\lambda)\overline{\theta} > (\frac{1}{\alpha^*} - 1 - \lambda)\frac{\nu}{1-\nu} \triangle \theta.$$

what, as is readily seen, equivalent to the following conditions:

$$\nu\overline{\theta} > \triangle \theta,$$

$$(1+\lambda)\overline{\theta} > \frac{1}{\alpha^*}\nu \triangle \theta + (1+\lambda)\nu\underline{\theta}.$$

Decision of majority-2 in the case typical for developing and transition economies For us the most interesting is the case

$$\frac{\nu}{\alpha^*} < 1 + \lambda < \frac{1-\nu}{\alpha^*}, \tag{16}$$

which seems to be typical for developing and transition countries, where the share $1-\nu$ of firms of type $\overline{\theta}$ in the economy is large. Note, that the left hand side of the inequality (16) means the admissibility of the separating mechanism under $\widetilde{K} > \overline{d}_2$ (see Section 3.1.2). The right hand side of (16) means a violation of conditions of feasibility of the pooling mechanism under $\widetilde{K} < \underline{d}_2$. Possible pollution levels are linked by the relation:

$$\underline{d}^* < \overline{d}_2 < \overline{d}^* < d_2^s < \underline{d}_2.$$

Hence, in a rather narrow interval $\overline{d}_2 < \widetilde{K} < d_2^s$ the feasibility conditions allow the majority-2 to employ both the pooling and the separating mechanisms. This case is especially interesting because the separating mechanism is employed through "large" $\widetilde{K}$ while the pooling mechanism is employed through "small" $\widetilde{K}$. In other words, the same value $\widetilde{K}$ appears to be "large" for the separating mechanism and "small" for the pooling mechanism. The mechanism for which the objective function is greater will be chosen; this depends, in particularly, on the kind of function $V(.)$.

Consider the case of quadratic function $V(d) = d^2$. We are interested, whether the type of the mechanism chosen by the majority-2 corresponds to the society's interests.

Theorem 1. *Let ν be small enough. If $\widetilde{K}$ is close to d_2^s and if $\widetilde{K} < d_2^s$ then the majority-2 will choose the separating mechanism and include into the menu of contracts the pollution levels $\underline{d}^*$ and d_2^s. This choice corresponds to the interests of the whole society. If $\widetilde{K}$ is close to $\overline{d}_2$ and $\widetilde{K} > \overline{d}_2$ then the majority-2 will choose the pooling mechanism and set the pollution level $\overline{d}_2$. This choice doesn't correspond to* *the interests of the society as the whole. Besides, the pollution levels are bound by the inequalities:*

$$\underline{d}^* < \overline{d}_2 < d_2^s.$$

Proof. The objective function of the majority-2 under the separating mechanism in the case of "large" $\widetilde{K}$ has the form:

$$W_2^{sep} = \alpha^*[\nu(S - V(\underline{d}) - (1+\lambda)(\kappa(\underline{\theta} - \underline{d\theta}) - \left(1 + \lambda - \frac{1}{\alpha^*}\right)(\kappa(\overline{\theta}) - \kappa(\underline{\theta}) - \overline{d}\Delta\theta)) +$$

$$+(1-\nu)(S - V(\overline{d}) - (1+\lambda)(\kappa(\overline{\theta}) - \overline{d\theta}))],$$

and under the unifying mechanism in the case of "small" $\widetilde{K}$ it has the form:

$$W_2^{un} = \alpha^*[\nu(S - V(d) - (1+\lambda)(\kappa(\underline{\theta}) - d\underline{\theta})) +$$

$$+(1-\nu)(S - V(d) - (1+\lambda)(\kappa(\overline{\theta}) - d\overline{\theta}) - \left(1 + \lambda - \frac{1}{\alpha^*}\right)(d\Delta\theta - \kappa(\overline{\theta} + \kappa(\underline{\theta}))))].$$

We will consider the limit behavior of the objective functions under $\nu \to 0$. Strict inequalities for the limit values will be held for sufficiently small values ν. We obtain

$$L^{sep} = \lim_{\nu\to 0} W_2^{sep} = \alpha^*[S - V(\overline{d}_2) - (1+\lambda)(\kappa(\overline{\theta}) - \overline{d}_2\overline{\theta})],$$

where

$$\overline{d}_2 = \frac{1}{2}\lim_{\nu\to 0} V'(\overline{d}_2) = \frac{1}{2}(1+\lambda)\overline{\theta} = \overline{d}^*;$$

$$L^{un} = \lim_{\nu\to 0} W_2^{un} = \alpha^*[S - V(d_2^s) - (1+\lambda)(\kappa(\overline{\theta}) - d_2^s\overline{\theta}) -$$

$$-\left(1 + \lambda - \frac{1}{\alpha^*}\right)(d_2^s\Delta\theta - \kappa(\overline{\theta}) + \kappa(\underline{\theta}))],$$

where

$$d_2^s = \frac{1}{2}\lim_{\nu\to 0} V'(d_2^s) = \frac{1}{2}\left[(1+\lambda)\underline{\theta} + \frac{\triangle\theta}{\alpha^*}\right] = \frac{1}{2}\underline{d}^* + \frac{\triangle\theta}{2\alpha^*}.$$

Consider two extreme cases.

First case. Let $\widetilde{K} < d_2^s$ but is sufficiently close to d_2^s for one may neglect the last terms in L^{un}. Then

$$L^{sep} - L^{un} = -\alpha^*\left(\frac{1}{2}(1+\lambda)\overline{\theta}\right)^2 + \alpha^*\left(\frac{1}{2}(1+\lambda)\underline{\theta} + \frac{1}{2}\frac{\triangle\theta}{\alpha^*}\right)^2 + \alpha^*\frac{1}{2}(1+\lambda)^2\overline{\theta}^2 -$$

$$-\alpha^*\frac{1}{2}(1+\lambda)^2\underline{\theta}\overline{\theta} - \alpha^*(1+\lambda)\frac{\overline{\theta}\triangle\theta}{2\alpha^*} = \frac{1}{4}(\triangle\theta)^2\alpha^*\left[\frac{1}{(\alpha^*)^2} - (1+\lambda)^2\right] > 0.$$

If ν is small and $\widetilde{K}$ is close to d_2^s and $\widetilde{K} < d_2^s$ then the majority-2 chooses a separating mechanism and, besides, the society's welfare function is equal to

$$W^{sep} = \frac{W_2^{sep}}{\alpha^*} + \nu\left(1 - \frac{1}{\alpha^*}\right)(\widetilde{K} - \overline{d}_2)\triangle\theta.$$

By using the pooling mechanism of "small" $\widetilde{K}$,

$$W^{un} = \frac{W_2^{un}}{\alpha^*} + (1-\nu)\left(1 - \frac{1}{\alpha^*}\right)(d_2^s - \widetilde{K})\triangle\theta.$$

Thus, $W^{sep} > W^{un}$, i.e. society's interests coincide with the choice of the interested sides.

Second case. Let $\widetilde{K} > \overline{d}_2$ but $\widetilde{K}$ be sufficiently close to $\overline{d}_2$ for the difference of the last term in L^{un} from $(d_2^s - \overline{d}_2)\triangle\theta$ might be neglected. Then

$$d_2^s - \widetilde{K} \to \frac{1}{2}\left[\frac{1}{\alpha^*} - (1+\lambda)\right]\triangle\theta$$

and therefore

$$L^{sep} - L^{un} = \frac{\Delta\theta^2}{4\alpha^*}[(\alpha^*)^2(1+\lambda)^2 + 1 - 2\alpha^*(1+\lambda) -$$
$$-2(1+\lambda)^2(\alpha^*)^2 + 4(1+\lambda)\alpha^* - 2] =$$
$$= -\frac{(\triangle\theta)^2}{4\alpha^*}[(1+\lambda)\alpha^* - 1]^2 < 0.$$

The majority-2 chooses the pooling mechanism if ν is small, and $\widetilde{K}$ is close to $\overline{d}_2$ and $\widetilde{K} > \overline{d}_2$.

Compare the social welfare functions:

$$W^{sep} - W^{un} = -\frac{(\triangle\theta)^2}{4(\alpha^*)^2}[(1+\lambda)\alpha^* - 1]^2 +$$
$$+\frac{1}{2}\left(\frac{1}{\alpha^*} - 1\right)\left[\frac{1}{\alpha^*} - (1+\lambda)\right](\Delta\theta)^2 > 0.$$

The separating mechanism is preferable for the society. Pollution levels are linked by the following relation:

$$\underline{d}^* = \underline{d}_2 < \overline{d}_2 < d_2^s.$$

4. Comparison of separating and pooling mechanisms under small $\triangle\theta$

Now we will investigate the situation where: 1) $\triangle\theta$ is small; 2) the choice of the kind of the mechanism (separating or pooling) is made either by the society or by the regulator (the majority-1 or the majority-2); 3) in accordance to a kind of the mechanism, the regulator sets a menu of contracts or a uniform contract.

One can tract the value $\triangle\theta$ as a result of deviation from the point $\widehat{\theta} = \overline{\theta} = \underline{\theta}$ by decreasing the value $\underline{\theta}$ or by increasing the value $\overline{\theta}$. Notice that in the point $\widehat{\theta}$ the following equality holds:

$$\underline{d}_1 = \overline{d}^2 = d_1^s = d_2^s = \underline{d}^*.$$

We will suppose in this Section that the function $\kappa(\theta)$ is differentiable, then an approximate equality is valid:

$$\widetilde{K} \approx \kappa'(\widehat{\theta}).$$

Further an analysis of the type of the mechanism is conducted on the base of a comparison of the values of the objective functions and of their derivatives by use of the envelope theorem (e.g. (Takayama, 1994)).

It is easily seen that in the point $\widehat{\theta}$ the social welfare for the separating and the pooling mechanisms coincides as well as its first derivatives (they are given below).

4.1. Case of "small" $\widetilde{K}$ (the firm of type $\overline{\theta}$ receives a rent)

Lemma 1. *Let the case of "small" $\tilde{K}$ take place, the society chooses the mechanism, and the regulator defines only the menu of contracts, and*

$$B = p(\lambda + 2\nu - 1)(1 + \lambda) + q\left(\lambda + 2\nu - 1 + \frac{1-\nu}{\alpha^*}\right)\left(1 + \lambda - \frac{1-\nu}{\alpha^*}\right).$$

Then:

1) under $B > 0$ the separating mechanism is preferable for the society,

2) under $B < 0$ the pooling mechanism is preferable for the society.

Proof. We will think about $\triangle\theta$ as about a result of decreasing $\underline{\theta}$ and compare mechanisms by second derivatives of the social welfare function in variable $\underline{\theta}$ in point $\widehat{\theta}$. These derivatives are calculated in the following parts I and II of the proof, and then in part III the comparison of the separating and the pooling mechanisms is made.

I. The separating mechanism.

I.i. The majority-1 is in power. The social welfare equals

$$W(\underline{\theta}) = \frac{W^1(\underline{\theta})}{\alpha^*} + (1-\nu)(\kappa(\underline{\theta}) - \kappa(\overline{\theta}) + \triangle\theta \underline{d}_1),$$

where $W^1(\underline{\theta})$ is the objective function of the majority-1 described by (7); the pollution levels $\underline{d}_1, \overline{d}^*$ are found in point 3.1.1. Applying to $W^1(\underline{\theta})$ the envelope theorem, we find

$$\frac{dW(\underline{\theta})}{d\underline{\theta}} = -(\lambda+\nu)(\kappa'(\underline{\theta}) - \underline{d}_1) + (1-\nu)\triangle\theta\frac{d\underline{d}_1}{d\underline{\theta}}.$$

It follows from (8) that

$$\frac{d\underline{d}_1}{d\underline{\theta}} = \frac{1+\lambda}{\nu V''(\underline{d}_1)}$$

$$\frac{d^2\underline{d}_1}{d\underline{\theta}^2} = -\frac{(1+\lambda)^2 V'''(\underline{d}_1)}{\nu^2[V''(\underline{d}_1)]^3}.$$

We find the second derivative of the social welfare function in point $\widehat{\theta}$:

$$\frac{d^2W(\underline{\theta})}{d\underline{\theta}^2}|_{\underline{\theta}=\widehat{\theta}} = -(\lambda+\nu)\kappa''(\widehat{\theta}) + \frac{(\lambda+2\nu-1)(1+\lambda)}{\nu V''(\underline{d}^*)}.$$

I.ii. The majority-2 is in power. The social welfare is

$$W(\underline{\theta}) = \frac{W^2(\underline{\theta})}{\alpha^*} + (1-\nu)\left(1 - \frac{1}{\alpha^*}\right)(\kappa(\underline{\theta}) - \kappa(\overline{\theta}) + \triangle\theta \underline{d}_2),$$

where $W^2(\underline{\theta})$ is the objective function of the majority-2 described by (10), $\underline{d}_2, \overline{d}^*$ are the pollution levels defined by the majority-2 (they are found in 3.1.2). Applying the envelope theorem to $W^2(\underline{\theta})$ we find

$$\frac{dW(\underline{\theta})}{d\underline{\theta}} = -(\lambda+\nu)(\kappa'(\underline{\theta}) - \underline{d}_2) + (1-\nu)\left(1 - \frac{1}{\alpha^*}\right)\triangle\theta\frac{d\underline{d}_2}{d\underline{\theta}}.$$

It follows from (11), that

$$\frac{d\underline{d}_2}{d\underline{\theta}} = \frac{1+\lambda-\frac{1-\nu}{\alpha^*}}{\nu V''(\underline{d}_2)}$$

$$\frac{d^2\underline{d}_2}{d\underline{\theta}^2} = -\frac{V'''(\underline{d}_2)}{[V''(\underline{d}_2)]^3}\left(\frac{1+\lambda-\frac{1-\nu}{\alpha^*}}{\nu}\right)^2.$$

In result in point $\widehat{\theta}$:

$$\frac{d^2W(\underline{\theta})}{d\underline{\theta}^2}|_{\underline{\theta}=\widehat{\theta}} = -(\lambda+\nu)\kappa''(\widehat{\theta}) + \left[\lambda+\nu-(1-\nu)(1-\frac{1}{\alpha^*})\right]\frac{1+\lambda-\frac{1-\nu}{\alpha^*}}{\nu V''(\underline{d}^*)}.$$

II. The pooling mechanism.

II.i. The majority-1 is in power. The social welfare equals

$$W(\underline{\theta}) = \frac{W^1(\underline{\theta})}{\alpha^*} + (1-\nu)(\kappa(\underline{\theta})-\kappa(\overline{\theta})+\triangle\theta d_1^s),$$

where $W^1(\underline{\theta})$ is the objective function of the majority-1, described by (13). The pollution level d_1^s, as is shown in subsection 3.2.1, equals $\underline{d}^*$. Analogously to the case of the separating mechanism, in point $\widehat{\theta}$,

$$\frac{d^2W(\underline{\theta})}{d\underline{\theta}^2}|_{\underline{\theta}=\widehat{\theta}} = -(\lambda+\nu)\kappa''(\widehat{\theta}) + \frac{(\lambda+2\nu-1)(1+\lambda)}{V''(\underline{d}^*)}.$$

II.ii. Majority-2 is in power. Society's welfare equals

$$W(\underline{\theta}) = \frac{W^2(\underline{\theta})}{\alpha^*} + (1-\nu)\left(1-\frac{1}{\alpha^*}\right)(\kappa(\underline{\theta})-\kappa(\overline{\theta})+\triangle\theta d_2^s),$$

where $W^2(\underline{\theta})$ is the objective function of the majority-2, described by equality (14). Pollution level d_2^s is defined by equation (15). Similarly to the case of separating mechanism, in point $\widehat{\theta}$,

$$\frac{d^2W(\underline{\theta})}{d\underline{\theta}^2}|_{\underline{\theta}=\widehat{\theta}} = -(\lambda+\nu)\kappa''(\widehat{\theta}) + \left[\lambda+\nu-(1-\nu)\left(1-\frac{1}{\alpha^*}\right)\right]\frac{1+\lambda-\frac{1-\nu}{\alpha^*}}{V''(\underline{d}^*)}.$$

III. Comparison of the separating and the pooling mechanisms in point $\hat{\theta}$.

The expected value of the second derivative of the social welfare under the separating mechanism is

$$D^{sep} = -(\lambda+\nu)\kappa''(\hat{\theta}) + \frac{B}{2\nu V''(\underline{d}^*)},$$

and under the pooling mechanism is

$$D^{un} = -(\lambda+\nu)\kappa''(\hat{\theta}) + \frac{B}{2V''(\underline{d}^*)}.$$

Preferable, from the point of view of the social welfare, is the mechanism with a greater value of the second derivative in $\underline{\theta}$. Let us stress that the sign of $\varDelta\theta$ (in this case it is negative) doesn't matter. Actually,

$$W(\underline{\theta}) = \frac{W''(\hat{\theta})}{2}(\varDelta\theta)^2 + o((\varDelta\theta)^2).$$

If $B > 0$ then $\frac{B}{V''(\hat{d})} < \frac{B}{\nu V''(\hat{d})}$ and the separating mechanism is preferable. If $B < 0$ then the pooling mechanism is preferable.

For us the most interesting case is the typical for the most of developing and transition economies one, when with a large probability the majority-2 is in power and "the share" of firm of type $\bar{\theta}$ is great, i.e. q is great, and condition (16) holds.

Theorem 2. *Let the case of "small" $\tilde{K}$ be considered and let $\Delta\theta$ be small. Under typical for developing and transition economies conditions, when condition (16) holds and q is sufficiency large, if the choice of type of mechanism is made by the society then the pooling mechanism will be chosen. If the majority-2 is in power and chooses both a mechanism and a menu of contracts then also the pooling mechanism will be chosen .*

Proof. In case under consideration, a sign of the magnitude B is defined by the second term which is negative. By Lemma 1, the unifying mechanism is preferable for the society.

Under condition (16) the condition of feasibility of the separating mechanism is violated, therefore the majority-2 will choose the pooling mechanism.

Theorem 3. *Let the case of "small" $\tilde{K}$ be considered and let $\Delta\theta$ be small. Under conditions when the "share" of the firms of type $\bar{\theta}$ in the economy is large (the condition (16) holds) and the majority-1 is in power this regulator chooses the separating mechanism, this coincides with the society's interests only if $\lambda + 2\nu - 1 > 0$. If $\lambda + 2\nu - 1 < 0$ then the unifying mechanism is preferable for the society. The pollution levels are linked by the relation:*

$$\underline{d}_1 < d_1^s = \underline{d}^* < \bar{d}^*.$$

Proof. In case of the separating mechanism the objective function of the majority-1 $W^1(\underline{\theta})$ is defined by Equation (7), and the pollution level $\underline{d}_1$ by Equation (8). In case of the pooling mechanism the objective function $W^1(\underline{\theta})$ is defined by Equation (13), the pollution level d_1^s equals $\underline{d}^*$. In point $\hat{\theta}$ the values of these functions coincide, the pollution levels coincide and equal $\underline{d}^*$, the first derivatives coincide and equal to

$$-\alpha^*(1+\lambda)(\kappa'(\underline{\theta}) - \underline{d}^*).$$

The second derivatives in these two cases are equal, correspondingly :

$$D^{sep} = \alpha^*(1+\lambda)\left[\frac{1+\lambda}{\nu V''(\underline{d}^*)} - \kappa''(\hat{\theta})\right],$$

$$D^{un} = \alpha^*(1+\lambda)\left[\frac{1+\lambda}{V''(\underline{d}^*)} - \kappa''(\hat{\theta})\right].$$

Thus, the majority-1 chooses the separating mechanism. If $\lambda + 2\nu - 1 > 1$, then, as is seen from Lemma 1, the society in whole would choose the separating mechanism, and if $\lambda + 2\nu - 1 < 1$ then the pooling mechanism.

4.2. The case of "large" $\tilde{K}$ (a rent is obtained by the firm of type $\underline{\theta}$)

As has been already said, the case of "large" $\tilde{K}$ seems to be typical for developed countries.

Lemma 2. *Suppose, that the society defines the type of the mechanism, and the regulator chooses the menu of contracts. The case of "large" $\tilde{K}$ is under consideration. Let the majority-2 be in power with a large probability (more exactly, p is so small that the sign of the magnitude*

$$C = p(1+\lambda)(1+\lambda-2\nu) + q\left[1+\lambda+-2\nu+\frac{\nu}{\alpha^*}\right]\left(1+\lambda-\frac{\nu}{\alpha^*}\right).$$

is defined by the second term), and the "the share" of firms of type $\bar{\theta}$ is sufficiently large (inequality $1+\lambda > \nu/\alpha^*$ holds). Then $C > 0$ and the separating mechanism is preferable for the society. If, under the same conditions, $1+\lambda < \nu/\alpha^*$ then the pooling mechanism is preferable for the society.

Proof. For "large" $\tilde{K}$ it is convenient, as it was done in (Laffont, 2000), to tract value $\Delta\theta$ as a result of increasing the magnitude $\bar{\theta}$. In parts I and II of the proof we will obtain an expression for the derivatives of the social welfare functions in $\bar{\theta}$ in point $\hat{\theta}$, and then in part III of the proof we will execute a direct comparison of the separating and the pooling mechanisms.

I. Separating mechanism.

I.i. The majority-1 is in power. The social welfare equals

$$W(\bar{\theta}) = \frac{W^1(\bar{\theta})}{\alpha^*} + \nu(\tilde{K}-\bar{d}_1)\Delta\theta = \frac{W^1(\bar{\theta})}{\alpha^*} + \nu(\kappa(\bar{\theta}) - \kappa(\underline{\theta}) - \bar{d}_1\Delta\theta),$$

where the objective function of the majority-1 $W^1(\bar{\theta})$ has the form:

$$W^1(\bar{\theta}) = \alpha^* E[S - V(d) - (1+\lambda)(\kappa(\theta)-\theta d) - (1+\lambda)U].$$

The pollution levels $\underline{d}^*$ and $\bar{d}_1$ are defined, correspondingly, by equations (9) and (2). Applying the envelope theorem to $W^1(\bar{\theta})$ we find:

$$\frac{dW^1(\bar{\theta})}{d\bar{\theta}} = \alpha^*[-\nu(1+\lambda)(\kappa'(\bar{\theta})-\bar{d}_1) - (1-\nu)(1+\lambda)(\kappa'(\bar{\theta})-\bar{d}_1)]$$

$$= -\alpha^*(1+\lambda)(\kappa'(\bar{\theta}-\bar{d}_1)$$

From (9) we find:

$$\frac{d\bar{d}_1}{d\bar{\theta}} = \frac{1+\lambda}{(1-\nu)V''(\bar{d}_1)},$$

$$\frac{d^2\bar{d}_1}{d\bar{\theta}^2} = -\frac{V'''(\bar{d}_1)}{V''(\bar{d}_2)}\left(\frac{d\bar{d}_1}{d\bar{\theta}}\right)^2 = -\frac{(1+\lambda)^2 V'''(\bar{d}_1)}{(1-\nu)^2[V''(\bar{d}_1)]^3}.$$

Applying the envelope theorem once more, we obtain

$$\frac{d^2W^1(\bar{\theta})}{d\bar{\theta}^2} = -\alpha^*(1+\lambda)\left(\kappa''(\bar{\theta}) - \frac{d\bar{d}_1}{d\bar{\theta}}\right).$$

Thus, for the social welfare function we have:

$$\frac{dW(\bar{\theta})}{d\bar{\theta}} = (\nu - 1 - \lambda)\kappa''(\bar{\theta}) + \frac{(1+\lambda-2\nu)(1+\lambda)}{(1-\nu)V''(\bar{d}_1)} + \frac{\mu(1+\lambda)^2 V'''(\bar{d}_1)}{(1-\nu)^2[V''(\bar{d}_1)]^3}\Delta\theta.$$

I.ii. The majority-2 is in power. The social welfare equals

$$W(\bar{\theta}) = \frac{W^2(\bar{\theta})}{\alpha^*} + \nu\left(1 - \frac{1}{\alpha^*}\right)(\tilde{K} - \bar{d}_2)\Delta\theta =$$

$$= \frac{W^2(\bar{\theta})}{\alpha^*} + \nu\left(1 - \frac{1}{\alpha^*}\right)(\kappa(\bar{\theta}) - \kappa(\underline{\theta}) - \bar{d}_2\Delta\theta),$$

where the objective function of the majority-2 $W^2(\bar{\theta})$ has the form

$$W^2(\bar{\theta}) = \alpha^* E\left[S - V(d) - (1+\lambda)(\kappa(\theta) - \theta d) - \left(1 + \lambda - \frac{1}{\alpha^*}\right)U\right].$$

The pollution levels $\underline{d}^*$ and $\bar{d}_2$ are defined, correspondingly, by relations (2) and (12). Applying the envelope theorem to $W^2(\bar{\theta})$ we find:

$$\frac{dW^2(\bar{\theta})}{d\bar{\theta}} = \alpha^*\left[-(1+\lambda)(\kappa'(\bar{\theta}) - \bar{d}_2) + \frac{\nu}{\alpha^*}(\kappa'(\bar{\theta}) - \bar{d}_2)\right].$$

From (12) we find:

$$\frac{d\bar{d}_2}{d\bar{\theta}} = \frac{1+\lambda-\nu/\alpha^*}{(1-\nu)V'''(\bar{d}_2)},$$

$$\frac{d^2\bar{d}_2}{d\bar{\theta}^2} = -\frac{(1+\lambda-\nu/\alpha^*)^2 V'''(\bar{d}_2)}{(1-\nu)[V''(\bar{d}_2)]^3}.$$

Applying the envelope theorem once more, we obtain:

$$\frac{d^2W^2(\bar{\theta})}{d\bar{\theta}^2} = \alpha^*\left[\left(\frac{\nu}{\alpha^*} - (1+\lambda)\right)\kappa''(\bar{\theta}) + \frac{(\nu/\alpha^* - (1+\lambda))^2}{(1-\nu)V''(\bar{d}_2)}\right]$$

Thus, we have for the social welfare function:

$$\frac{d^2W^2(\bar{\theta})}{d\bar{\theta}} =$$

$$= (\nu - 1 - \lambda)\kappa''(\bar{\theta}) + \left(1 + \lambda - 2\nu + \frac{\nu}{\alpha^*}\right)\frac{1+\lambda-\nu/\alpha^*}{(1-\nu)V''(\bar{d}_2)} +$$

$$+\nu\left(1 - \frac{1}{\alpha^*}\right)\frac{(1+\lambda-\nu/\alpha^*)^2 V'''(\bar{d}_2)}{(1-\nu)^2[V''(\bar{d}_2)]^3}\Delta\theta.$$

II. The unifying mechanism.

II.i. The majority-1 is in power. The social welfare equals

$$W(\bar{\theta}) = \frac{W^1(\bar{\theta})}{\alpha^*} + \nu(\kappa(\bar{\theta}) - \kappa(\underline{\theta}) - d_1^h\Delta\theta),$$

where the objective function of the majority-1 $W^1(\bar{\theta})$ has the form:

$$W^1(\bar{\theta}) = \alpha^*[S - V(d_1^h) - (1+\lambda)(\nu(\kappa(\underline{\theta}) - \underline{\theta} d_1^h) + (1-\nu)(\kappa(\bar{\theta}) - \bar{\theta} d_1^h)) -$$

$$-\nu(1+\lambda)(\kappa(\bar{\theta}) - \kappa(\underline{\theta}) - d_1^h \Delta\theta)].$$

The pollution level d_1^h is defined by the equation

$$V'(d_1^h) = (1+\lambda)(\nu\underline{\theta} + (1-\nu)\bar{\theta}) + \nu(1+\lambda)\Delta\theta = (1+\lambda)\bar{\theta}. \qquad (17)$$

Hence, $d_1^h = \bar{d}^*$. Applying to $W^1(\bar{\theta})$ the envelope theorem, we find:

$$\frac{dW^1(\bar{\theta})}{d\bar{\theta}} = \alpha^*[-(1+\lambda)(1-\nu)(\kappa'(\bar{\theta}) - d_1^h) - (1+\lambda)\nu(\kappa'(\bar{\theta}) - d_1^h)] =$$

$$= -\alpha^*(1+\lambda)(\kappa'(\bar{\theta}) - d_1^h).$$

From (17) we obtain:

$$\frac{dd_1^h}{d\bar{\theta}} = \frac{1+\lambda}{V''(d_1^h)},$$

$$\frac{d^2 d_1^h}{d\bar{\theta}^2} = -\frac{V'''(d_1^h)}{V''(d_1^h)}\left(\frac{dd_1^h}{d\bar{\theta}}\right)^2 = -\frac{(1+\lambda)^2 V'''(d_1^h)}{[V''(d_1^h)]^3}.$$

Applying the envelope theorem once more we obtain:

$$\frac{d^2 W^1(\bar{\theta})}{d\bar{\theta}^2} = -\alpha^*(1+\lambda)\left(\kappa''(\bar{\theta}) - \frac{dd_1^h}{d\bar{\theta}}\right) = -\alpha^*(1+\lambda)\left(\kappa''(\bar{\theta}) - \frac{1+\lambda}{V''(d_1^h)}\right).$$

Thus, for the social welfare function:

$$\frac{dW(\bar{\theta})}{d\bar{\theta}} = -(1+\lambda)(\kappa'(\bar{\theta}) - d_1^h) + \nu(\kappa'(\bar{\theta}) - d_1^h) - \nu\frac{dd_1^h}{d\bar{\theta}}\Delta\theta,$$

$$\frac{d^2 W(\bar{\theta})}{d\bar{\theta}^2} = (\nu - 1 - \lambda)\kappa''(\bar{\theta}) + (1+\lambda-2\nu)\frac{1+\lambda}{V''(d_1^h)} + \nu\frac{(1+\lambda)^2 V'''(d_1^h)}{[V''(d_1^h)]^3}\Delta\theta.$$

II.ii. Majority-2 is in power. Social welfare equals

$$W(\bar{\theta}) = \frac{W^2(\bar{\theta})}{\alpha^*} + \nu\left(1 - \frac{1}{\alpha^*}\right)(\kappa(\bar{\theta}) - \kappa(\underline{\theta}) - d_2^h \Delta\theta),$$

where the objective function of the majority-2:

$$W^2(\bar{\theta}) = \alpha^*[S - V(d_2^h) - (1+\lambda)(\nu(\kappa(\underline{\theta}) - \underline{\theta} d_2^h) + (1-\nu)(\kappa(\bar{\theta}) - \bar{\theta} d_2^h)) -$$

$$-\nu\left(1+\lambda - \frac{1}{\alpha^*}\right)(\kappa(\bar{\theta}) - \kappa(\underline{\theta}) - d_2^h \Delta\theta)].$$

The pollution level d_2^h is defined from equation:

$$V'(d_2^h) = (1+\lambda)(\nu\underline{\theta} + (1-\nu)\bar{\theta}) + \nu\left(1+\lambda - \frac{1}{\alpha^*}\right)\Delta\theta = (1+\lambda)\bar{\theta} - \frac{\nu}{\alpha^*}\Delta\theta. \qquad (18)$$

Applying to $W^2(\bar\theta)$ the envelope theorem we find:

$$\frac{dW^2(\bar\theta)}{d\bar\theta} = \alpha^*\left[-(1+\lambda)(\kappa'(\bar\theta)-d_2^h) + \frac{\nu}{\alpha^*}(\kappa'(\bar\theta)-d_2^h)\right].$$

From (18) we obtain:

$$\frac{dd_2^h}{d\bar\theta} = \frac{1+\lambda-\nu/\alpha^*}{V''(d_2^h)},$$

$$\frac{d^2d_2^h}{d\bar\theta^2} = -\frac{(1+\lambda-\nu/\alpha^*)^2V'''(d_2^h)}{(1-\nu)[V''(d_2^h)]^3}.$$

Applying the envelope theorem once more, we obtain:

$$\frac{d^2W^2(\bar\theta)}{d\bar\theta^2} = \alpha^*\left[\left(\frac{\nu}{\alpha^*}-(1+\lambda)\right)\kappa''(\bar\theta) + \frac{(\nu/\alpha^*-(1+\lambda))^2}{V''(d_2^h)}\right].$$

Thus, for the social welfare function we have:

$$\frac{d^2W(\bar\theta)}{d\bar\theta^2} = (\nu-1-\lambda)\kappa''(\bar\theta) + \left(1+\lambda-2\nu+\frac{\nu}{\alpha^*}\right)\frac{1+\lambda-\nu/\alpha^*}{V''(d_2^h)}+$$

$$+\nu\left(1-\frac{1}{\alpha^*}\right)\frac{(1+\lambda-\nu/\alpha^*)^2V'''(d_2^h)}{[V''(d_2^h)]^3}\Delta\theta.$$

III. Comparison of the separating and the pooling mechanisms in point $\hat\theta$.

In the point $\hat\theta$ (when $\Delta\theta$=0) the values of the social welfare function for the separating and the pooling mechanisms coincide, the pollution levels $\bar d_2$ and d_2^h coincide and equal $\underline{d}^*$, the first derivatives also coincide. The expected value of the second derivative of the social welfare under the separating mechanism is equal to:

$$D^{sep} = (\nu-1-\lambda)\kappa''(\hat\theta) + \frac{C}{(1-\nu)V''(\underline{d}^*)},$$

and under the unifying mechanism:

$$D^{un} = (\nu-1-\lambda)\kappa''(\bar\theta)+$$

$$+\left[p(1+\lambda-2\nu)(1+\lambda) + q\left[\lambda+1-\nu-\nu\left(1-\frac{1}{\alpha^*}\right)\right]\left(1+\lambda-\frac{\nu}{\alpha^*}\right)\right]\frac{1}{V''(\underline{d}^*)} =$$

$$= (\nu-1-\lambda)\kappa''(\hat\theta) + \frac{C}{V''(\underline{d}^*)}.$$

It is clear, that

$$\lambda+1-\nu-\nu\left(1-\frac{1}{\alpha^*}\right) > \lambda+1-\nu > 0,$$

so the sign of C under small p is defined by the sign of $1+\lambda-\nu/\alpha^*$. If $1+\lambda > \nu/\alpha^*$ then $C>0$, then the separating mechanism is preferable for the society. If $1+\lambda < \nu/\alpha^*$ then $C<0$ and the unifying mechanism is preferable for the society.

Theorem 4. *In the case of "large" $\widetilde{K}$ if the majority-2 is in power and chooses both the mechanism and the menu of contracts, and the condition $\nu/\alpha^* < 1+\lambda$ (condition of feasibility of the separating mechanism) holds, then the majority-2 chooses the separating mechanism. Besides, the pollution levels are linked by the following relation:*

$$\underline{d}^* < d_2^h < \bar{d}_2.$$

If $\nu/\alpha^* > 1+\lambda$ then only the pooling mechanism is available.

Proof. In the point $\hat{\theta}$ (where $\Delta\theta = 0$) the values of the objective function of the majority-2 for the separating and the pooling mechanisms coincide, the pollution levels $\bar{d}_2$ and d_2^h coincide and equal $\underline{d}^*$, the first derivatives also coincide. The second derivatives in these two cases are equal, correspondingly to:

$$D^{sep} = \alpha^* \left[\left(\frac{\nu}{\alpha^*} - (1+\lambda) \right) \kappa''(\bar{\theta}) + \frac{(\nu/\alpha^* - (1+\lambda))^2}{(1-\nu)V''(\underline{d}^*)} \right] =$$

$$= (\nu - \alpha^*(1+\lambda))\kappa''(\hat{\theta}) + \frac{\alpha^* V''(\underline{d}^*) G^2}{1-\nu}$$

and

$$D^{un} = (\nu - \alpha^*(1+\lambda))\kappa''(\hat{\theta}) + \alpha^* V''(\underline{d}^*) G^2,$$

where

$$G = \frac{\nu/\alpha^* - (1+\lambda)}{V''(\underline{d}^*)}.$$

Thus, independently on relation between values ν/α^* and $1+\lambda$, the majority-2 will choose the separating mechanism.

Theorem 5. *In the case of "large" $\tilde{K}$, if the majority-1 is in power and chooses both the mechanism and the menu of contracts then it will choose the separating mechanism.*

Proof. In the point $\hat{\theta}$ ($\Delta\theta = 0$) the values of the objective function of the majority-1 for the separating and the pooling mechanisms coincide, the pollution levels $\bar{d}_1$ and d_1^h coincide and equal $\underline{d}^*$, the first derivatives coincide. The second derivatives in these two cases are equal:

$$D^{sep} = -\alpha^*(1+\lambda) \left(\kappa''(\hat{\theta}) - \frac{1+\lambda}{(1-\nu)V''(\underline{d}^*)} \right)$$

and

$$D^{un} = -\alpha^*(1+\lambda) \left(\kappa''(\hat{\theta}) - \frac{1+\lambda}{V''(\underline{d}^*)} \right).$$

Thus, the majority-1 will choose the separating mechanism.

4.3. Discussion of results

The results of research are brought in Tables 1 and 2.

Table 1 corresponds to the case which seems to be typical for many developing and transition economies: "dirty" firms are relatively effective and their share in

Table1: The choice of the kind of the mechanism and the pollution level under "small" $\tilde{K}$ and small ν (by $\nu < 1 - (1+\lambda)\alpha^*$)

Who sets mechanism	Who sets contracts menu	Admissible pollution levels	What a mechanism is chosen
Society	Majority-1	$\underline{d}^*$	Pooling
	Majority-2	d_2^s	
Majority-2	Majority-2	d_2^s	
Majority-1	Majority-1	$\underline{d}_1 \quad \overline{d}^*$	Separating

Table2: Choice of kind of mechanism and pollution levels by "large" $\tilde{K}$

Who sets the mechanism	Who sets contracts menu	Admissible pollution levels	What a mechanism is chosen
Society	Majority-1	$\overline{d}^*$, if $\nu > \frac{1+\lambda}{2}$	Pooling
		$\underline{d}^* \quad \overline{d}^1$, if $\nu < \frac{1+\lambda}{2}$	Separating
Society or Majority-2	Majority-2	d_2^h, if $\nu > (1+\lambda)\alpha^*$	Pooling
		$\underline{d}^*$ and $\overline{d}_2$, if $\nu < (1+\lambda)\alpha^*$	Separating
Majority-1	Majority-1	$\underline{d}^* \quad \overline{d}^1$	Separating

the economy, $1-\nu$, is relatively large. Moreover, feasible pollution levels are linked by the relation:

$$\underline{d}_1 < \underline{d}^* < \bar{d}^* < d_2^s,$$

Table 2 corresponds the case typical for developed country where "green" firms are relatively efficient. In this case the following relations between admissible pollution levels hold:

If $\nu > (1+\lambda)\alpha^*$ then $d_2^h < \underline{d}^* < \bar{d}^* < \bar{d}_1$.

If $\nu < (1+\lambda)\alpha^* < 1$ then $\underline{d}^* < d_2^h < \bar{d}_2 < \bar{d}^* < \bar{d}_1$.

If $\nu < 1 < (1+\lambda)\alpha^*$ then $\underline{d}^* < d_2^h < \bar{d}^* < \bar{d}_2 < \bar{d}_1$.

Notice that in all cases considered in Table 2 the share of "green" firms ν may be either higher or wittingly higher than in the cases considered in Table 1. The situations represented in Table 1 and Table 2, in our opinion, quite correspond to economic conditions in developing and transition economies and in developed countries, correspondingly.

Comparing the right parts of the tables, we see, that the employment of the separating (market) mechanism may be expected in a more degree in developed countries than in developing and transition economies.

In the case typical for developing and transition economies (Table 1) the greater pollution level d_2^s of "green" firms is reached under the pooling mechanism when the interested majority sets the menu of contracts.

On the contrary, in the case typical for developed countries (Table 2) the majority-2 appears to be the most effective ecological regulator.

Table 2, however, allows to make another conclusion: when the share of "green" firms in the economy increases, one may expect in developed countries a higher degree of pooling mechanism employment.

5. Conclusion

In this paper on base of the contracts theory the work of an ecological policy mechanism is studied under different conditions, including both economic components (economic efficiency of different types of firms and their "share" (frequency) in the economy) and a political component (who namely – the society or the regulator – makes decision concerning the type of the mechanism – pooling or separating, who is in power and makes decision about admissible pollution levels). Analysis shows that under the same frame mechanism its variety and the resulting economical policy depend considerably on these conditions.

Thus, the research put under doubt a broadly spreading view about a possibility of an adequate transfer into an arbitrary taken transition or developing economy of the institutions which have proved themselves perfect in one or another developed country.

References

Davis, S.-J., Caldeira, K. (2010). *Consumption-based accounting of CO2 emissions*. Proceedings of National Academy of Sciences of the USA, **107(12)**, 5687–5692.

Hawksworth, J. (2006). *Implications of global growth for carbon emissions and climate change policy*. Pricewaterhouse Coopers.

Laffont, J.-J. (2000). *Incentives and political economy*. Oxford: Oxford University Press.

Matveenko, V. D. (2010). *Incentive mechanisms in ecologicaly motivated regulation: Will ecologic policies in transition and developing economies become effective?* Journal of New Economic Association, **8**, 10–34. (Russian).

Takayama, A. (1994). *Analytical methods in economics*. New York: Harvester Wheat Sheaf.