LEGAL SOLUTIONS AND ECOLOGICAL INNOVATIONS IN ORGANIZATIONS

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Abstract

Ecological innovations can be implemented in an organization in a voluntary or forced manner. In the former case, organizations take a decision to modernize the technologies used on the basis of socio-economic premises. In the latter one – tightening legal regulations brings about a necessity of a change of the installations used. In such a situation, emission standards or technological standards are subject to change, which makes it necessary to for organizations to adjust to new demands, determined in legal regulations. In the article the relationships holding between ecological innovations and legal regulations pertaining to environmental protection was presented. The study results show that legal regulations do not affect ecological innovations to such an extent as it was originally assumed. In spite of the fact that these regulations provide a principal source of ecological innovations, their impact results mainly from the sanctionary character of legislation. 

Keywords: environmental innovation, legal regulations, organization.

Introduction

A decision-taking process in an organization, based on an analysis of economic costs/gains and long-term objectives, often leaves out an analysis of expenses/effects related to environmental protection. It results from a strong pressure of competition which causes organizations to use a mechanism of transferring costs to third parties thanks to which there is an increase of an organization’s profits. On the other hand, an appropriate quality of the natural environment constitutes a generally socially acceptable objective and is not limited to selected entities. In this situation, there arises a need to force organizations into certain behaviours. Behaviours which are aimed at achieving socially acceptable objectives. In the case of environmental protection, this tendency to internalize external costs is always attained by means of instruments of ecological policy: legal, economic, psychosocial. This discussion is limited to legal solutions. They involve regulations of a structural character, which define rights and obligations of business entities concerning the use and protection of the environment, as well as rules which regulate financial and organizational problems, the legal importance and character of ecological policy. The aim of the regulations is to safeguard, by means of legal norms, such a system of social and economic relations which would completely eliminate harmful and undesirable changes in the environment, or which would prevent its degradation (Brzezinski, 1975).

According to the literature on the subject, legal regulations provide a major incentive to implement ecological innovations. They force organizations, irrespective of their strategy, to comply with the binding emission standards and technological standards. Legal responsibility compels organizations to adjust their installations to legal requirements. On the other hand, the relationships holding between environmental regulations and ecological innovations are very tight. At the same time, in Central-Eastern European countries, their character has not been fully recognized. Consequently, the aim of this article is to present the relationships holding between ecological innovations and legal regulations pertaining to environmental protection, and in particular to acquire an answer to the question: do environmental regulations impact ecological innovations, including: the amount of RD spending, the range of implemented ecological innovations.

This paper is organized as follows: the next section characterizes, in general terms, the environmental protection law binding in Poland. Section 3 presents the essence of ecological innovations, whereas the following one deals with their relations with legal regulations. Section 5 summarizes hitherto prevailing studies concerning the impact of legal solutions on innovative activities in the area of environmental protection. The remaining two sections present the study method (section 6) and the results of the empirical studies conducted (section 7).

Environmental protection law in Poland

Generally speaking, in Polish environmental protection law one can distinguish several layers of legal regulation of statutory importance (Paczuski, 1996):
• constitutional rules,
• comprehensive legal regulation of the law on environmental protection [LEP], involving:
  o a set of legal norms determining directions of activities, fundamental principles of environmental protection law,
  o a set of legal norms regulating certain areas in a direct and detailed manner,
  o a primary legal LEP regulation which determines the main stipulations and primary objectives and refers to special regulations on detailed issues,
• special regulations which LEP refers to,
• sozological legal norms.

Legal acts defining the elements of the environmental management system, specifically those which establish the principles and terms of environmental use involve: The Law on Environmental Protection, Water Law, the Act on Waste, the Act on Land Planning and Development. The most comprehensive, original legal act is the Law on Environmental Protection of 27th Apr 2001. This act was made the “leading act” in relation to the whole legislation concerning the issues of environmental protection. The systematics of the act is divided into the following topics: general regulations, environmental resources protection, pollution prevention, serious accidents, financial and legal resources, liability, administrative bodies and environmental protection institutions, adjustment schemes. The act, together with other specialized legal acts, plays a number of functions, including (Machowski, 2000):
• an organizational one, which consists in creating a legal and political framework of environmental protection by means of legal instruments,
• a regulatory and protective one, based on the introduction of legal restrictions of environmental use,
• a protective one with relation to entities’ rights, the aim of which is to satisfy claims,
• of an incentive for economic processes encouraging environmentally friendly activities,
• of implementation of technological advance as an instrument of development and consolidation of scientific and technological advance,
• a repressive one, which is based on establishing penal sanctions for violation of regulations.

A feature of environmental protection law as a legal system is the fact that it is an open system, which is a consequence of the essence of protection issues. Constant development of production forces and introduction of novel constructional and technological solutions bring about an increase of ever new threats requiring a legislative intervention, and thus the introduction of amendments or supplementations of the existing legislation or completely new legal regulations (Dziadosz, 2007).

From the point of view of economic entities, the act and the implementing provisions, to a large extent define these entities’ obligations concerning environmental protection, considering that:
• bans refer to activities or substances,
• regulations concern specific activities with reference to which respectively limitations or restrictions are applied, determined by various kinds of standards,
• bans and regulations concerning environmental protection are implemented by means of:
  o permits, certificates, admittances, concessions granted before a scheme is launched,
  o later specifications and direct orders.

Organizations’ most important obligation resulting from current legal regulations is the obligation of rational resources management and of compliance with the allowed norms. In the former case, in compliance with the act an entrepreneur is obliged to use resources only to an extent justified by social interest, the assessment of which takes into account, except for recommendations of a long-term economic calculation, also the significance of resources in preserving environmental balance and a balance of living conditions, giving priority to undertakings which enable an economical use of resources, not worsening the state of the environment (Górka et al., 1998). The second case refers to compliance with arrangements contained in water use licences, decisions on allowed pollution emission into the atmosphere, decisions on the allowed level of noise and vibrations. It is also connected with the use of appropriate technologies which pose a minimum threat to the environment. The abovementioned obligations are addressed at economic entities, nevertheless they need to be individualized in each case, e.g.: by environmental protection services. The
extent to which regulations are complied with is verified by supervisory bodies, first of all by PIOŚ. Its main area of activity is the control of regulations on environmental protection and a rational use of resources as well as an assessment of the state of the environment.

Infringement of the obligations results in legal liability which may be of an administrative, civil or penal character. By administrative liability one can understand legally regulated capacity to initiate legal measures, in the forms and procedure specific for administration, against a particular entity which disturbs the state of the environment. Administrative liability is independent of blame. Sanctions can be applied even when there is only a threat of a health or environmental hazard.

Organizational activities of administrative bodies consist in issuing decisions i.e. planning decisions, decisions on allowed emission, on delineating landfill sites, permits of hazardous waste production, on imposing pecuniary penalties for breaking requirements, interventional. Administrative procedures result in decisions which:

- impose on an entity an obligation to reduce a negative environmental impact,
- order an entity to restore the environment to its proper state,
- impose an obligation to pay monetary sums for environmental damage if it is impossible to restore the previous state,
- impose pecuniary penalties,
- suspend activities which constitute a serious environmental hazard or which endanger human health.

Effectiveness of administrative measures is conditioned by instruments of administrative enforcement - penalties. They are essentially incurred for exceeding or violating terms of environmental use determined by decisions with respect to: gases and dusts discharged into the air, wastewater discharged into waters, water consumption, waste storage. A premise for determining the amount of penalties is the legal principle of causation and the PPP formula.

Civil liability in environmental protection is used in the case of defining (Domański, 1976): activities of an entity polluting the environment as unlawful, a causative relationship between activities of a particular entity and environment devastation, the extent of the reparable damage in the form of monetary damages.

It can assume the form of compensation for a damage already caused (compensatory liability) or an obligation to refrain from a certain activity which prevents a damage (preventative). Civil measures are applied when administrative measures taken under the law turn out to be ineffective. It results from the fact that their efficiency is to a great extent limited – it is necessary to prove the lawlessness and a cause and effect relationship, which is a criterion of holding entities liable. Whereas penal liability is of an individual character. It is necessary, then, to define an offence as an abstract threat, in which subject to penalty is the violation of environmental protection regulations and to extend penalization by making punishable acts preceding the occurrence of the effect (Radecki, 1976). However, an essential loophole in the PC is the inability to call a legal entity to justice. Yet experience shows that behaviours of collective entities are primary sources of threats (Laguna et al.). Thus, one of the ways of reinforcing the role of penal law (in environmental protection) should be to introduce an institution of penal liability of legal entities and other organizational units and economic entities.

The actual state of the binding environmental protection law in a normative sense differs from the other components of the law in force, which is a consequence of the fact that the primary objectives and the main stipulations of environmental protection law converge with a worldwide environmental protection strategy based on the UN documents. Therefore, in many areas domestic environmental protection law forms a symbiosis with international law. It is based on general principles of community law, i.e.:

- the principle of subsidiarity,
- the principle of solidarity,
- the principle of priority of community law over the legal orders of the member states,
- the principle of direct application and direct effect of compliance with community law in a domestic legal order.

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1 Inspection activities are in certain areas also carried out by the Supreme Chamber of Control [NIK], PIS-E, the Office for Construction Supervision, the State Services of Radioactive Contamination Measurements.
Respecting the significance of the indivisible unity of the natural environment, Poland is a party to numerous legal and international instruments concerning its broadly conceived protection. From the point of view of europeization of national law, in the years 1997-2003, in Poland 360 bills were passed in order to harmonize domestic law with the EU law (Sommer, 2004). Extensive transformations were made so as to adjust it to the demands of the European Union. Numerous multilateral agreements concerning environmental protection, to which Poland is a party, involve a vast array of issues ranging from protection of circunterrestrial space to protection of the world natural heritage. Among the new institutions, one can indicate specifically integrated emission permits, an introduction of the principle of the best available technology, a system of decisions connected with waste management. The introduction of a chemical substance and product control system is worth emphasizing. Other essential novelties also involve an introduction of an extensive scheme and programme system aimed at environmental protection and improvement of its state. Currently, Polish law is undergoing unification. It involves a faithful transfer of certain regulations, directives as well as changes in Polish legislation connected with implementation of community regulations, which are directly binding and exclude the existence of domestic regulations in this respect (Habuda, 2006).

**Ecological innovations**

According to the OECD division, an organization’s innovative actions involve organizational and technological innovations, which can additionally be subdivided into product and process ones. The division also applies to ecological activities. And thus, ecological technological innovations constitute a specific type of innovations which comprises modified products and processes the objective of which is to limit or reduce environmental pollution (Rennings & Zwick, 2002). An example of process innovations are end of pipe innovations and integrated technologies. On the other hand, organizational innovations involve reorganization of processes and a range of responsibilities in order to limit impact on the environment. They can be a factor promoting technological changes; they can also be introduced independently. In industrial practice, an improvement of ecological characteristics of production or of a product is most frequently achieved through the implementation of technological innovations. In legal regulations they are frequently referred to as installations which are:

a) stationary technical devices,
b) a complex of technologically connected stationary technical devices, to which the same entity is vested with a legal title and which are located on the premises of one establishment,
c) facilities which are not technical devices or their complexes, the exploitation of which can cause emission.

Installations have to comply with the requirements of the best available technology (BAT). It was assumed that the best available technology is the most effective and advanced level of development of technology and methods of conducting a certain type of activities, used as a basis for determining maximum emission amounts, the aim of which is to eliminate emission or if that is not possible, to reduce emission and its impact on the environment as a whole, considering that:

- technology denotes the technologies used, as well as a manner in which a particular installation is designed, constructed, exploited or liquidated,
- available technologies mean technologies of such a level of development which allows their practical use in a given branch of industry, taking into account the economic and technical conditions and the calculation of investment costs and benefits for the environment, and which techniques are available to the entity conducting the activities,
- the best technology means the most effective technology in achieving a high level of protection of the environment as a whole (art. 3, item 10 of the Act on Environmental Protection (AEP)).

Until recently, most actions in the area of environmental protections focused mainly on the final stages of production processes. They are based on the use of protective devices of the so called end-of-pipe, which only minimize a negative impact on the environment. Therefore, these technologies do not eliminate the causes of pollution production but their effects. As a matter of fact, they reduce the toxicity of pollution produced by transforming it into a different type of pollution (Fijał, 2005). The use of end-of-pipe technologies was based on a static approach, where the main incentive to reduce adverse effects on the environment was the principle the polluter pays, which put a financial burden on pollution producers (Cichy, 2007). Its opposite is a dynamic approach in which emphasis is put on minimizing the amounts of pollution produced “at the source”. Thus, it is based on cleaner production technologies characterized by (Fijał, 2005):
• an economical use of raw materials and energy carriers,
• elimination of raw materials hazardous for the environment and human health,
• prevention of pollution production by means of changes in a production structure,
• recycling waste, unreacted raw materials and minerals, as well as used up products,
• manufacturing products which are safe for the environment.

The objective of such technological innovations is elimination and prevention of waste production, its emission and minimizing the use of resources. Thus, it is possible to reduce the consumption of water, resources, energy and the amount of technological waste produced.

Technological ecological innovations are used mainly in production processes, where conventional, linear production systems are exchanged for cyclical systems based on closed material cycles. In particular, these innovations are based on modernization of technology and machine parks, reconstruction of workshops. A selection of new technological solutions to be implemented should take into account the impact of particular elements of a production process on its course, changes of products, of the technological regime and of the technological process itself, which would improve ecological characteristics of production.

Environmental regulations and innovations

Economic development is directly dependent on the natural environment. The significance of the environment is based on the fact that it (Machowski, 2000): 1) provides localization and enables the development of socio-economic activities in a given area, 2) is the source of resources, 3) is a waste receiver, 4) has resources which are consumer goods. A dynamically developing economy, which is on the one hand based on natural resources, on the other one generates pollution, begins to exert pressure on the environment. Simultaneously, the capacity of the environment is limited – it is impossible to exceed the allowed scale of economic development without causing irreversible ecological changes. Therefore, the assessment of environmental impact [OOS] is an important legal and economic institution in economic activities. It contains an estimate of anticipated direct, indirect short and long-term effects on particular elements of the environment, as well as a comparison of suggested technological solutions with others, considering optimum protective capacities. It is connected with norms of an optimum level of environmental pollution established by the legislator, compliance with which is necessary to obtain an integrated permit (by organizations which might have a significant environmental impact through pollution of particular elements of the environment or the environment as a whole). Such an approach guarantees reduction of the impact of installations on the environment to a level justified by technological and economic considerations. However, complying with legally defined requirements does not signify a specific technology. An entrepreneur has the right to choose a technology from among those which comply with the standards. Additionally, one can distinguish installations and technical devices, which are products of human activity, which contain mechanisms or sets of mechanisms. In compliance with AEP such a distinction comes down to the fact that an installation is a stationary object, whereas a device is not. However, both installations and devices have to comply with standards of results or technology. As far as standards of results are concerned, organizations are free to select means of ensuring compliance (Dupuy, 1997). It enables organizations to make a flexible choice of innovations which serve to obtain a desirable level of pollution abatement. On the other hand, technology standards are determined by technological specifications – therefore they characterize BAT criteria. The development of a more effective technology in the case of these standards makes it necessary for all organizations to adapt them.

Compliance with legal requirements does not mean buying ever new, more efficient purifying installations. An emphasis is placed on an ongoing improvement by putting into practice a strategy of cleaner technology. From the point of view of technological innovations, techniques described in best available technologies reference documents provide only a reference point. Therefore, it is necessary to carry out an ongoing modernization of production processes “in little steps.” This will enable:

• the use of substances of a reduced threat potential,
• a more effective energy use and production,
• a more rational use of water and other resources and materials,
• the use of wasteless and low-waste technologies and a possibility of recycling produced waste,

As well as assessments of a life cycle, assessments of ecological options, risk assessments, ecological characteristics of technology and product used in economic practice.
• a use of comparable processes and methods which have been efficiently used on an industrial scale,
• scientific and technological advance.

Taking into account newly constructed and modernized facilities, in the light of AEP they cannot be commissioned if they do not comply with environmental protection standards, i.e. (Jendroška & Bar, 2005):
• introduction of technological measures of environmental protection required by the regulations or in administrative decisions,
• the application of appropriate technological solutions resulting from acts, decisions,
• obtaining required decisions determining the range and terms of environmental use,
• keeping by research and tests required by the law.

In a situation when an organization uses technologies which do not comply with the required standards, it can implement an adjustment scheme. Its purpose is compliance with the binding requirements of those installations which for technological or economic reasons cannot comply with these requirements within the deadlines provided by the generally binding regulations. Thus, when extreme values determined by BAT are objectives which organizations can temporarily comply with only to a limited extent, they can provide another step on the way to the implementation of a dynamic approach to environmental protection. Under such circumstances, the adjustment scheme put in place consists in implementing innovations which enable technology to comply with the requirements resulting from the best available technology or to remove damages caused by previous exploitation.

As well as technological impacts, regulations have also stimulated a range of organizational impacts, involving changes in management or working practices (Murphy & Gouldson, 2000). Technological and organizational changes have commonly been required in combination to ensure that the technological responses to regulation are successfully integrated into existing systems. However despite their combined importance it is still possible to identify explicitly organizational innovations which have occurred as a result of technical regime. These are equally important and in some cases more important, than the technological solutions upon which attention commonly focuses.

Ecological innovations and legal solutions in the light of empirical studies

In the 1990-s researchers were in general agreement that influence requirements have on progress concerning environmental technology is minor (Faber et al., 1989). This approach was questioned by Corfee (1992) according to whom command and control systems do not always have negative impacts on technological progress. For example regulatory bans have sometimes forced the development and penetration of new pollution control technologies. It was borne out by Porter and Van der Linde’s studies (1995) who presented examples of organizations which showed a competitive advantage thanks to innovations implemented in response to an increase of stringency of legal regulations concerning environmental protection. They also confirmed that appropriate regulations create possibilities of eliminating ineffective use of resources, of reducing uncertainty concerning the value of environmental investments, of creating demand for clean products. Thereby, they can provide an incentive motivating organizations to implement new processes and innovative products. Therefore, Porter and van der Linde depart from the traditional standpoint indicating that environmental regulations not only exert pressure on organizations to implement ecological innovations, but these innovations can stimulate the development and competitiveness of organizations. While the latter claim is subject to much criticism and debate, the former claim is both plausible and testable.

Other studies were conducted by Lanjouw and Mody (1996) based on patent data from 1972-1986 in order to study the creation and diffusion of environmental technologies. They used costs of pollution abatement as an indicator of severity of environmental regulations and find that innovation follows expenditures with a 1 to 2 year lag. Jaffe and Palmer (1997) construct a panel a data set to determine how abatement expenditures affect innovative activities. Innovation is proxied by two different measures: total industry expenditures on RD, and total number of successful patent applications by industry. They find that higher lagged abatement costs lead to higher levels of RD expenditure. However when they use patent applications as an indicator of innovation, they find little evidence that they are related to abatement costs. Pickman obtained different results, according to which there exists a positive correlation between regulation as measured by contemporary or lagged PACE and environmental innovation when estimated by ordinary least squares (Pickman, 1998). He proved that environmental regulations causes industry to innovate in an environmental direction but diverts resources from other types of innovation without however causing a decline in total
innovation. Brunnermeier’s studies (Brunnermeier & Cohen, 2003) were of an analogous character and they involved 146 American organizations and data from the years 1983-1992. They were aimed at determining the dependence between expenditures on environmental protection and ecological innovations (measured as environmental patents applied for). Brunnermeier’s results confirm that these variables are connected with one another – about a 0.04 % increase in patents per 1 million $ in pollution abatement expenditures.

Taking into account the relationship between stringency of environmental regulation and incentives for RD and technology diffusion – there also has been some research. For example, Oates (Oates et al., 1993) use simple model of profit-maximizing firm in a perfectly-competitive industry to show that increasing the level of pollution tax rate increases the firm’s incentive to adopt a more efficient abatement technology. Schmalensee (1994) suggests that while research and development devoted to environmental compliance may increase with stricter environmental regulation this increase will likely come at the expense of other research efforts that could have been more profitable. McCain (1978) notes that regulated firms may be reluctant to innovate or to adopt more efficient pollution control technologies if they anticipate that any resulting gains in the efficiency of pollution control will lead to subsequent tightening of regulatory standards.

Compared with other instruments, requirements are considered to be rather innovation-impeding. Since residual emissions do not result in costs for emitter and consequently the emitter is no longer interested in more far-reaching emission-reducing measures. Such incentive would only exist if through innovations in field of environmental technology which decrease operating cost, emissions would fall short of the limit. This however could turn out to be a disadvantage for organizations. The reductions achieved could indicate to the authorities that further emission reductions are technically feasible and further tightening of the requirements possible so that other installations too have to comply with the more stringent requirements and further costs ensue (Georg et al., 1992). The research carried out so far suggests that intensification of control activities causes an increase in compliance with the law and an improvement of environmental results (Magat & Viscusi, 1990). However, it was not confirmed whether an increase in the monitoring of control bodies leads to an increase in innovative activities. These issues have not been subject to research in Poland, either.

**Model and data**

The main objective of the research was to analyze relationships between legal environmental regulations and ecological innovations, in particular to determine whether regulatory compliance costs overestimated when technological advancement is not accounted for ex ante estimates of regulatory costs. Two indicators were used to assess the level of eco-innovativeness of organizations:

- investment outlays incurred by organizations for RD activities in the sphere of environmental protection,
- effects of environmental protection investments commissioned in a given year, including: 1) water treatment facilities, 2) capacity of devices to reduce dust and gas pollution.

The measure in the form of the number of patents was not used in the course of the study due to its frequent criticism in the literature of the subject. Since not all firms need to be innovators, a number of worked out solutions (even of an innovative character) are not patented, whereas in economic practice most of the implemented innovations are of an imitative character.

The research quoted in the literature suggests that environmental regulatory goals impose costs upon firms. Potential savings on abatement costs provide incentives for firms to utilize resources to develop new pollution abatement technology that will decrease their marginal abatement cost. Firms innovate if the expected cost savings from innovation are greater than the costs of innovation. In accordance with these presuppositions, it was assumed that the stringency of the law affects innovative activities by influencing environmental protection costs. Based on the previous research, the PACE indicator was used (pollution abatement and control expenditures) as a measure of regulatory burden under the assumption that when regulations are tightened firms will spend more on abatement. Although we expect PACE to increase when regulations are tightened other factors might also cause PACE to increase. Thus if firms overcomply with existing regulations this could also be reflected in increased PACE. However we do not distinguish between regulatory and overcompliance pressures.

The following research models were adopted in order to assess the relationships between ecological innovations and environmental regulations:

\[
BR = b_0 + b_1 \text{Control} + b_2 \text{PACE} + \varepsilon \quad (1)
\]
where:
bi – model parameters,
ε – random factor,
BR – investment expenditures on research and development,
GP – capacity of devices to abate gas pollution,
WT – water treatment (facilities),
PACE – current environmental protection costs in the economic sector,
Control – inspected organizations.

**Empirical results**

Table 1 presents a list of basic indicators for the whole country, during the period under research, for all variables used in the research.

In the light of the obtained results the PACE coefficient of 0,28 represents the semi-elasticity of BR with respect to PACE. Specifically, mean BR are expected to increase when costs increase by 1000PLN. Thus, I estimate that the magnitude of this impact is economically high but statistically not significant.

Whereas in the case of implemented innovations there occurs an essential, though negative correlation between the number of water treatment facilities and the number of inspections conducted (-0,79) and PACE (-0,57) and a negative correlation between the variables and the capacity to reduce pollution emitted into the atmosphere (-0,50; -0,26 respectively).

**Table 1. Summary statistics**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR</td>
<td>Thousand PLN</td>
<td>3636,781</td>
<td>140,500</td>
<td>10132,00</td>
<td>3513,174</td>
</tr>
<tr>
<td>WT</td>
<td>Piece</td>
<td>286,55</td>
<td>56,00</td>
<td>897,00</td>
<td>185,955</td>
</tr>
<tr>
<td>GP</td>
<td>Dam³</td>
<td>115,68</td>
<td>4,00</td>
<td>430,00</td>
<td>122,217</td>
</tr>
<tr>
<td>Control</td>
<td>Piece</td>
<td>14019,07</td>
<td>11203,00</td>
<td>16876,00</td>
<td>1506,206</td>
</tr>
<tr>
<td>PACE</td>
<td>Mln PLN</td>
<td>7002,42</td>
<td>1402,20</td>
<td>9545,00</td>
<td>2061,006</td>
</tr>
</tbody>
</table>

According to Fig. 1 there is a positive correlation between the number of inspections and environmental protection costs. The relationship between RD activities, on the one hand, and the number of inspections and the costs, on the other one, is not completely unequivocal which results from a significant difference in amounts of RD spending. A weak positive dependence can be observed in the 1990-s, nevertheless in the subsequent years the amount of resources allocated for RD activities was radically reduced. Hence, there is a negative correlation between these variables. A similar tendency can be observed in the case of the number of water treatment facilities, whose number began to decrease after 2000. On the other hand, the number of innovations used for air pollution abatement is of a very unsteady character, due to which the relationship between them and the studied variables is not quite clear.

**Figure 1. Variables in 1994-2007**
The analysis of the dispersion diagram conducted suggests that it is of a linear character in the case of implemented innovations and curvilinear in the case of RD spending. Since the dispersion diagram does not unambiguously point to a particular curve, I considered the following models concerning the RD variable: a second-degree polynomial, a third degree polynomial, a natural logarithm, a decimal logarithm. Based on the results and on the compatibility measure, it was concluded that logarithmic transformation is the most congruent, according to which 54% of RD variability is accounted for by independent variables. Similarly, the statistical error of estimation of the transformed model is relatively small (0.46), and thus random variability is small. Multiple regression was successively conducted for this model (Tab. 2).

**Table 2. Regression analysis results – the RD dependent variable**

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.735</td>
</tr>
<tr>
<td>R2</td>
<td>0.540</td>
</tr>
<tr>
<td>Corrected r2</td>
<td>0.438</td>
</tr>
<tr>
<td>F</td>
<td>5.29</td>
</tr>
<tr>
<td>p</td>
<td>0.030</td>
</tr>
<tr>
<td>Stat. error</td>
<td>0.467</td>
</tr>
<tr>
<td>BETA Control</td>
<td>-1.148</td>
</tr>
<tr>
<td>BETA PACE</td>
<td>0.627</td>
</tr>
<tr>
<td>t Control</td>
<td>-2.95</td>
</tr>
<tr>
<td>t PACE</td>
<td>1.61</td>
</tr>
<tr>
<td>p Control</td>
<td>0.015</td>
</tr>
<tr>
<td>p PACE</td>
<td>0.140</td>
</tr>
</tbody>
</table>

The variation analysis showed that the value of F statistics is 5.29 for the 0.03 validity. The statistics is higher than the critical value (4.75), and thus at the 0.05 level of validity one can reject a hypothesis of the non-existence of a regressive relationship between the variables. T-Student statistics values at a 0.05 validity level lead to the rejection of a hypothesis that the number of inspections does not affect the amount of RD spending (p=0.01) and the ascertainment of a lack of validity of the impact of the amount of costs (0.14). A positive value of regression coefficients proves a positive impact of the PACE variable on the RD variable, but of a converse one for the number of inspections. The determination coefficient corrected due to the number of degrees of liberty indicates that the 43% model accounts for the RD variable. The amount of random deviations of the model is 0.46.

In the case of implemented innovations, the F test results indicate that there is a connection between the number of water treatment facilities and at least one explaining variable (at the 0.01 validity level – Tab.3). According to the test the number of inspections (p=0.03) is the t variable which helps to explain the variability of this kind of innovations, at a statistically significant level.

**Table 3. Regression analysis results – the WT, GP dependent variables**

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>WT</td>
<td>0.747</td>
</tr>
<tr>
<td>R2</td>
<td>WT</td>
<td>0.558</td>
</tr>
<tr>
<td>Corrected r2</td>
<td>WT</td>
<td>0.470</td>
</tr>
<tr>
<td>F</td>
<td>WT</td>
<td>6.332</td>
</tr>
<tr>
<td>p</td>
<td>WT</td>
<td>0.016</td>
</tr>
<tr>
<td>Stat. error</td>
<td>WT</td>
<td>151.99</td>
</tr>
<tr>
<td>BETA</td>
<td>Control</td>
<td>-1.109</td>
</tr>
<tr>
<td>BETA</td>
<td>PACE</td>
<td>0.436</td>
</tr>
<tr>
<td>t</td>
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<td>-2.405</td>
</tr>
<tr>
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</tr>
<tr>
<td>p</td>
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</tr>
<tr>
<td>p</td>
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Taking into account a punctual assessment of regression coefficients for the GP variable we ought to ascertain that they are respectively -0.11%, 0.05% with the mean random error of 0.04% and 0.03%. The declared validity level (0.05) is lower than the critical validity level and therefore the zero hypothesis is not rejected. On the other hand, since the critical level is only slightly higher than the adopted level, the verification decision is blurred. It is confirmed by the variation analysis results, where the value of F statistics is 3.83 with a 4.75 critical value.

Regression results showed that mean variations of the dependent variable are determined by variations of independent variables, respectively in 55% (water treatment facilities) and 43% (gas pollution abatement). Thus, for the number of water treatment facilities the correlation coefficient is $\phi^2=0.45$. Gas pollution abatement innovations are influenced by the remaining cause sources in 57%. On the other hand, the partial correlations analysis showed that the PACE variable contributes to a small extent to the prediction of the value of the dependent variable (0.28; 0.43 – a weak correlation), whereas the Inspections variable is characterized by a non-linear dependence, of a greater degree of interrelationship.

Conclusions

From the industry perspective placing the emphasis as much on the techniques of environmental management as on the technologies has had a considerable impact. In most cases organizations, with the help of the regulator, have identified areas for environmental improvement which entail almost no investment and improve both environmental and economic performance.

The research conducted shows that legal regulations have a certain, though not such a significant as previously indicated, impact on innovative activities in the area of environmental protection. They affect the creation of ecological innovations in 54% and their implementation in 50%. Taking into account the independent variables used in the research, one needs to conclude that an increase of PACE is connected with a slight, but statistically significant increase of the number of ecological innovations. This is in line with the results of previously conducted studies. A low value of correlation results from the omission of innovations implemented by the state sector, i.e. RD companies, universities, consulting agencies. However, in the course of the studies a significant influence of the number of inspections on innovative activities was not proved. On the other hand, the results obtained indicate that, at a statistically significant level, inspections are negatively correlated with the creation (RD) and implementation (WT, GP) of innovations.

In the light of correlation analysis results, an increase of current costs is linked to an increase in the number of inspections carried out. It is certainly caused by performance of post-inspection recommendations which generate additional costs. Under such circumstances, these financial means do not additionally reinforce the funds allocated to carry out research work. Moreover, it is worth emphasizing that there is a significant difference in spending on RD activities in subsequent years, which certainly narrows down the process of creation of ecological innovations in numerous organizations. The range of research work may also be limited because of an organization’s fears. It is caused by the fact that the development of new technologies can bring about a tightening of the existing standards, which will in effect force organizations to incur further investment outlays.

The results of research suggests that the strengths of regulations stem from the sustained interaction with a relatively export regulator involved in the building of environmental capacity in firms, rather than from the imposition of imperatives for environmental improvement. Therefore, the influence of legal regulations results from their stringency, whereas the environmental protection law which is in force in Poland does not generate extra incentives encouraging the implementation of ecological innovations. Thus, the realization of the country’s ecological policy requires a combination of incentives of a sanctionary character (regulations) and of instruments which stimulate an organization to undertake voluntary pro-ecological activities such as for e.g.: economic instruments.

The findings suggest the need for further research in understanding the relationship between legal solutions and ecological innovations. A natural extension of the research conducted is to draw international comparisons. It also seems advisable to perform studies which would take into account the division of ecological innovations into integrated and end-of-pipe ones, which would assess the expenditures of ensuring the compatibility and effectiveness of their use and also those which would study the impact of the stringency of the law on pro-ecological activities undertaken in various sectors.
References


