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Environmental insurance analysis from an economic approach

Abstract

The aim of this research work is to propose which features in environmental insurance provide the best incentives to agents, so that they shall take actions towards promoting good care practices for the environment as well as for natural resources. In the second section of this work, a model, based on information theory, is introduced in order to study the behavior of agents when faced with incentives provided by environmental insurance policies. Then, an empirical analysis, describing the regulations in force and the current situation of environmental insurance for a particular case, i.e., Argentina, is shown. Finally, the features, emerging from the theoretical model, are confronted with those observed in the market. Results suggest that there is a great similarity in how some concepts are dealt with, while, in others, there are substantial differences. Consequently, policy proposals can be made to improve the situation in this matter.

Keywords: environmental damage, environmental risk, insurance, adverse selection, asymmetric information, optimal contract, incentives.

Introduction

The aim of this research work is to propose which features in environmental insurance provide the best incentives to agents, so that they shall take actions towards promoting good care practices for the environment as well as for natural resources.

In the first Section, a summary of the major landmarks on the topic of insurance and, in particular, of environmental insurance from an economic point of view is presented. Then, a conceptual model, based on the theory of information economics, is presented in order to study the behavior of agents when faced with optimal incentives in environmental insurance. Next, an empirical analysis, describing the regulations in force and the current situation of environmental insurance for a particular case, i.e. Argentina, is shown. Finally, the features, emerging from the theoretical model, are confronted with those observed in the market. Results suggest that there is a great similarity in how some concepts are dealt with, while, in others, there are substantial differences.

This work offers to the reader an analysis of environmental insurance from a theoretical and empirical point of view, establishing the features that cause a contract to provide the adequate incentives so that the behavior of agents shall tend to protect both the environment and natural resources. Consequently, policy proposals can be made to improve the situation in this matter.

1. Motivation and background

Traditional textbooks in microeconomics – such as Mas-Colell, Whinston & Green (1995), Kreps (1995), Fernandez de Castro & Tugores Ques (1992), among others – show a Section devoted to the study about the theory of information economics that presents the problems, arising, in particular, from information asymmetries, i.e., adverse selection and moral hazard. In such problems, there is an adverse selection situation as the one in which the principal cannot recognized the agent type before signing the contract, while moral hazard is a situation in which the principal cannot observe the agent's decisions during the development of the contractual relationship.

Rothschild & Stiglitz (1976) have introduced, more than three decades ago, a basic model on equilibrium in the market of competitive insurance. The main results are that equilibrium, if it exists, depends on price and quantity specification, not only prices; that high hazard individuals exert a dissipation of externalities on low hazard ones; and that the structure of equilibrium, as well as the existence thereof, only exists under a large number of assumptions that are inconsequent with perfect information.

Laffont (1995) studies potential conflicts between cost reduction and risk taking in a natural monopoly regulation context. One of the main conclusions, he reaches, is that the insurance for major hazards cannot be left in the hands of the market.

In particular with regard to environmental issues, in the European Union there is a document, called White Paper on Environmental Liability, published in the year 2000, that supplies legal regulations, focusing on environmental liability, mainly on the damage caused to biodiversity in protected natural areas. This document intends to explore how the "polluter pays" principle could better serve the region's cooperation intentions, taking into account that avoiding environmental damage is the main objective of the policies.

Based on the White Paper, Faure (2003) studies the insurability of environmental hazard, in general, and environmental liability for damages on natural resources, in particular. The analyses contained in this research are not only centered on damage coverage through insurance, in the traditional sense, but also

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on financial security agreements, such as compensation funds and other alternatives. The analysis, carried out, has mainly a legal approach instead of an economic one. There is a distinction between unilateral environmental accidents, implying that the victim does not affect the occurrence probability of the event, and bilateral environmental accidents – the affected party also has an influence on the accident hazard. In both situations, it is necessary to distinguish between risky and non-risky activities. Taking into account this classification of cases, an analysis of the circumstances, under which it is convenient to use subjective liability systems (negligence rules), is carried out, i.e., when there is the need to prove negligence or fraud, and under which it is convenient to use objective liability systems (strict liability rules), in which it is irrelevant to prove negligence or fraud.

2. Theoretical model

2.1. Intervening parties. There are several parties in an environmental damage insurance policy: the insurance company, the potentially polluting entity, the state, and the identified victim or affected party. Not all these parties take part in the first theoretical model, introduced in Section 2.2. However, it is worth to bear in mind all potential participants of the problem.

Table 1. Parties in an environmental insurance problem

Insurance company (A)	Potentially polluting entity (C)
♦ offers a certain prime in exchange for returning the money to restore the damage caused, in case the event occurs; ♦ does not know the type and effort made by C so as not to damage environmental quality; ♦ participates as PRINCIPAL in the information asymmetric relationship.	♦ transfers the accident hazard to A in case it takes out an insurance policy; ♦ knows its own type and is the one who decides the level of effort to make so as to reduce the occurrence probability of an event, causing environmental damage; ♦ participates as AGENT in the information asymmetric relationship.
State (E)	**Victim or affected party (D)**
♦ sets forth laws and regulations to protect the environment and the elements that form it; ♦ may work as a mediator in the environmental valuation of the issue, the value of the damage caused; ♦ may act as a PRINCIPAL, maximizing social utility subject to conditions for the participation of the rest of the parties.	♦ the victim may be an individual or a group of individuals, collective incidence damage, society in general, and/or future generations; ♦ it may be represented by the state; ♦ within the scope of environmental insurance, most cases are unilateral accidents.

Source: Compiled by the authors

2.2. The conceptual model. Environmental insurance constitute an adverse selection case simultaneously with moral hazard. The problem arises before subscribing the contract because the insurance company (principal) does not know the environmental hazard of the potentially polluting entity (agent). And the second, problem arises after subscribing the contract since the principal does not know the effort that the agent will make, in order to avoid or reduce the probability of the accident that shall cause the environmental damage.

Next, an environmental insurance model, in which an insurance company takes part as principal and a potentially polluting company as agent, ensuring a sum that is equal to the value of damage, is introduced. Potential extensions to the basic model are introduced next.

2.2.1. Basic model with one principal and one agent:

1. Insurance prime (P).

The environmental insurance prime is a growing function in environmental damage occurrence probability and the extent thereof (equation 1).

$$P = F\left[p(e), L_C\right], \tag{1}$$

where $p(e)$ is the occurrence probability of the accident causing the environmental damage during the period, that depends on the effort (e) made by the potentially polluting individual or legal entity (C) to avoid it, a variable not directly observable by the insurance company (A). Thus, in this case, the agent is the potentially polluting entity (C) and the principal is the insurance company (A). The occurrence probability for the accident, causing the environmental damage, decreases with the increase in the agent's effort, but at a decreasing rate. This implies that:

$$\frac{\partial p(e)}{\partial e} < 0,$$

$$\frac{\partial^2 p}{\partial e^2} < 0.$$

L_C is the extent of environmental damage, calculated by means of the valuation methodology for natural resources that best matches the features of environmental damage intended to be assessed. Therefore, one may use the method-factor matrix (Pesce, Vigier & Durán, 2009b). When the damage can be completely repaired, L_C may be calculated as:

$$L_c = \sum_{t=0}^{T} \frac{CR_t}{(1+R)^t}, \tag{2}$$

where CR_t are restoration costs for a period t that are updated at a rate R and added in time. The temporal horizon T refers to the number of temporal units that complete restoration of damage shall take.

When damage cannot be restored, a methodology, based on demand functions, could be used through declared preferences, such as contingent valuation, joint analysis or choice experiments. In addition, there

are some methods that intend to infer preferences through the behavior of individuals, such as travel expenses. In this case, money for irreversible damage, cannot be used to restore the damage, but it may constitute a fund to compensate affected parties or it may be used for direct regulations by the state.

When damage affects the production function of a company, the company's productivity variation method may be used (Pesce, Vigier & Durán, 2009a). And when damage is not an externality, consequently, the environmental effect is reflected in the pricing system of an economy, one can resource to valuation by means of hedonic price functions.

Finally, it is worth mentioning that the prime for an environmental insurance contract, calculated as $P = p(e) \cdot L_C$, meets the requirements of the so-called actuarially fair prime that is equal to the occurrence probability of the event by the damage amount. In this case, it is only established that the prime is a function of those variables but the functional form is not specified.

2. Efforts, states of nature, and occurrence probabilities.

In this simple model it is supposed that the agent can only make two types of effort: great or low effort, denoted by e^A and e^B, respectively.

In addition, two states of nature are acknowledged. In one of them, that happens with a probability $p(e)$, damage occurs (D), and in the other, it does not (ND).

Then, occurrence probabilities for D and ND, considering the agent's effort are:

- $p(e^A)$, the occurrence probability of D, being that the agent makes a great effort, and its complement, the probability that D does not occur (i.e., ND) under the same level of effort $[1 - p(e^A)]$;
- $p(e^B)$, the occurrence probability of D, being that the agent makes a low effort, and its complement, the probability that ND shall occur under the same level of effort $[1 - p(e^B)]$.

Due to the facts described above, it applies that $p(e^A) < p(e^B)$, and, therefore, $[1 - p(e^A)] < [1 - p(e^B)]$.

3. Function of incremental expected benefits of the insurance company (π_A):

$$\pi_A = P(e) - C_A - p(e) \cdot L_C, \tag{3}$$

where the first term represents the prime charge that depends on the effort. Since effort is a non-observable variable, the principal looks for variables correlated to it so as to establish the amount of the prime, such as the costs paid for preventing environmental damage. The second term ($-C_A$) is a variable that includes administrative, auditing, and control costs. And the last one is the one that adds risk to the expected benefit function, and represents the accident cost expectation, that is expressed in detail in equation 4.

$$p(e) \cdot L_c + (1 - p(e)) \cdot 0 = p(e) \cdot L_C. \tag{4}$$

The benefit margin of the insurance company depends on the structure of its market. If such market is competitive, the benefit is null. In this case, it is supposed that there are excess benefits, thus, the market is not competitive. Those benefits shall be maximized in the solution to the problem, subject to certain restrictions.

4. Expected utility function of the potentially polluting entity (u_c).

The potentially polluting entity may be an individual or a legal entity. The analysis should not change substantially since companies are run by individuals that are subject to being sued, although, it is more traditional to make the analysis for one individual. Thus, preferences in case of risk can be reflected. In this case, it is supposed that the agent is risk adverse, therefore, his/her utility function is strictly convex. The analytical expression for the expected utility, weighing the results in each of the states of nature, is shown in equation 5.

$$u_C = p(e) \cdot u[L_C - P(e) - C(e)] + \\ + (1 - p(e)) \cdot u[- P(e) - C(e)], \tag{5}$$

where $p(e)$ is the occurrence probability for environmental damage, is the agent's utility function, L_C (within the utility function) is the saving obtained for not having to cope with the cost of restoring environmental damage, is the prime cost; and $C(e)$ are the costs of the effort to avoid the accident. This last term is a way to signal the non-observable variable: the effort. Costs increase positively with effort, that is:

$$\frac{\partial C(e)}{\partial e} > 0.$$

5. Problem to solve.

To maximize the benefit expected from the principal: $\pi_A = P(e) - C_A - p(e) \cdot L_C$.

Subject to the following restrictions:

- agent's participation condition:

$$E(u_C) = p(e^A) \cdot u[L_C - P(p(e^A)) - C(e^A)] + \\ + (1 - p(e^A)) \cdot u[- P(p(e^A)) - C(e^A)] > \overline{u}_C,$$

where $\overline{u}_C$ is the reserve utility, a constant value lower than the agent's expected utility making a great effort.

- incentive compatibility condition:

$$E\left(u_C\left(e^A\right)\right) = p\left(e^A\right)\cdot u\left[L_C - P\left(p\left(e^A\right)\right) - C\left(e^A\right)\right] +$$
$$+\left(1 - p\left(e^A\right)\right)\cdot u\left[- P\left(p\left(e^A\right)\right) - C\left(e^A\right)\right] \geq$$
$$\geq p\left(e^B\right)\cdot u\left[L_C - P\left(p\left(e^B\right)\right) - C\left(e^B\right)\right] +$$
$$+\left(1 - p\left(e^B\right)\right)\cdot u\left[- P\left(p\left(e^B\right)\right) - C\left(e^B\right)\right].$$

This means that the agent's expected utility making a great effort has to be greater (or equal) to the one that derives from a low effort.

6. Results and proposals.

Next, the result matrices for the principal (Table 2) and the agent (Table 3) are shown, taking into account the type of effort made by the agent and the state of nature, i.e. if the environmental damage occurs (D) or not (ND). In the last row of each case, the expected value under that problem specification is shown.

Table 2. Result matrix for the principal

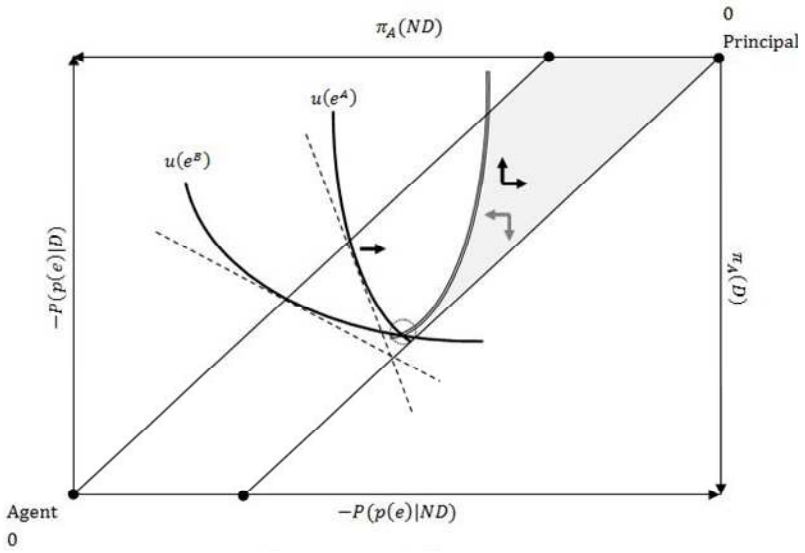
If the agent's effort is great	
If *D*	$\pi_A(D) = P\left(p\left(e^A\right)\right) - C_A - L_C$
If *ND*	$\pi_A(ND) = P\left(p\left(e^A\right)\right) - C_A$
Expected value	$E\left(\pi_A\left(e^A\right)\right) = p\left(e^A\right)\cdot\left[P\left(p\left(e^A\right)\right) - C_A - L_C\right] + \left(1 - p\left(e^A\right)\right)\cdot\left[P\left(p\left(e^A\right)\right) - C_A\right]$
If the agent's effort is low	
If *D*	$\pi_A(D) = P\left(p\left(e^B\right)\right) - C_A - L_C$
If *ND*	$\pi_A(ND) = P\left(p\left(e^B\right)\right) - C_A$
Expected value	$E\left(\pi_A\left(e^B\right)\right) = p\left(e^B\right)\cdot\left[P\left(p\left(e^B\right)\right) - C_A - L_C\right] + \left(1 - p\left(e^B\right)\right)\cdot\left[P\left(p\left(e^B\right)\right) - C_A\right]$

Source: Compiled by the authors

Table 3. Result matrix for the agent

If the agent's effort is great	
If *D*	$\mathrm{u}_C(D) = u\left[L_C - P\left(p\left(e^A\right)\right) - C\left(e^A\right)\right]$
If *ND*	$\mathrm{u}_C(ND) = u\left[- P\left(p\left(e^A\right)\right) - C\left(e^A\right)\right]$
Expected utility	$E\left(u\left(e^A\right)\right) = p\left(e^A\right)\cdot u\left[L_C - P\left(p\left(e^A\right)\right) - C\left(e^A\right)\right] + \left(1 - p\left(e^A\right)\right)\cdot u\left[- P\left(p\left(e^A\right)\right) - C\left(e^A\right)\right]$
If the agent's effort is low	
If *D*	$\mathrm{u}_C(D) = u\left[L_C - P\left(p\left(e^B\right)\right) - C\left(e^B\right)\right]$
If *ND*	$\mathrm{u}_C(ND) = u\left[- P\left(p\left(e^B\right)\right) - C\left(e^B\right)\right]$
Expected utility	$E\left(u\left(e^B\right)\right) = p\left(e^B\right)\cdot u\left[L_C - P\left(p\left(e^B\right)\right) - C\left(e^B\right)\right] + \left(1 - p\left(e^B\right)\right)\cdot u\left[- P\left(p\left(e^B\right)\right) - C\left(e^B\right)\right]$

Source: Compiled by the authors



Source: Compiled by the authors

Fig. 1. Dynamics of the principal-agent problem

The results and the problem dynamics are shown in Figure 1, using a model similar to Edgeworth box.

The straight lines at 45°, that begin at the agent's and principal's origin respectively, that end in solid circles so as to be identifiable, are certainty lines. On those lines, the result obtained by each of the participants in the problem is the same, regardless the state of nature that occurs. Function u (e^B) is the agent's indifference curve when making a low effort, while u (e^A) corresponds to the case when the agent makes a great effort. It should be noticed that the slope of such utility curve is higher in absolute values. The indifference curve, given the low effort e^B, cuts the agent's certainty line with a slope equal to the quotient of the probabilities $-\left(1-p\left(e^B\right)\right)/\,p\left(e^B\right)$ that correspond to e^B. While the indifference curve, when the effort is great e^A, presents a slope of $-\left(1-p\left(e^A\right)\right)/\,p\left(e^A\right)$, greater to the former in absolute values[1]. This happens because damage (and no damage) occurrence probabilities depend on the effort made by the agent, therefore, the curves present different slopes. For the agent's participation restriction have to be fulfilled, expectations from the great effort have to be greater than a reserve utility $\overline{u}_C$.

The utility would be greater in the points, located above, and to the right of the Edgeworth box. In addition, the incentive compatibility condition should be fulfilled and for this the offered contract should be located on the double curve, in case of fulfilling the restriction with equality, or to the right thereof [2]. The black arrows show the area towards which the agent's restrictions are fulfilled. On the other hand, the principal tries to maximize his/her benefits, for which he/she shall look for contracts located below and to the left that are the ones that provide the best results for him/her. The grey arrows represent the principal's maximization dynamics. The feasible area for contracts is in grey and the limit contract is enclosed in a non-continuous circle: at that intersection point the principal maximizes his/her benefits, fulfilling the agent's incentive participation and compatibility restrictions so as for him/her to make the great effort.

Proposition 1. The supply of environmental insurance contracts with constant prime does not show the proper incentives for agents to make the great effort.

The explanation for this proposal is intuitive. If the prime charged is the same, the benefit of a greater effort is absorbed by the principal, since he/she shall obtain $\pi_A = \overline{P} - C_A - p\left(e^A\right)\cdot L_C$, being the last term lower than $p\left(e^B\right)\cdot L_C$. However, the agent will never choose to make the great effort $\left(e^A\right)$, since with the constant prime, the expected utility is $p\left(e^A\right)\cdot u\left[L_C - \overline{P} - C\left(e^A\right)\right] + \left(1-p\left(e^A\right)\right)\cdot u\left[-\overline{P} - C\left(e^A\right)\right]$ in case of making the great effort, and $p\left(e^B\right)\cdot u\left[L_C - \overline{P} - C\left(e^B\right)\right] + \left(1-p\left(e^B\right)\right)\cdot u\left[-\overline{P} - C\left(e^B\right)\right]$ for the low effort, being $C\left(e^A\right) > C\left(e^B\right)$ and $p\left(e^A\right) < p\left(e^B\right)$.

Proposition 2. An agent adverse to risk obtains a higher utility if he/she transfers the risk to the principal, by means of an environmental insurance policy. On the contrary, an agent neutral to risk prefers the self-insurance option.

The explanation for this proposal lies in the traditional result that arises from the case in which the effort is non-observable and the agent is neutral to risk, the same happens under perfect observability of the effort. In this case, the optimal contract consists in transferring the business risk to the agent, as if he/she were the "owner" of the project, and, in this way, he/she will choose the greater effort. This illustrated situation does not reflect a framework in which the insurance is a viable alternative. Indeed, the agent is self-insured.

Proposition 3. Any contract outside the grey area in Figure 1 is a contract without optimal incentives for the agent, thus, the effort of the potentially polluting entity to avoid environmental damage shall be lower, in the case of having only two types of effort, it shall be the low effort, occurrence probability shall be greater and, therefore, the prime charged shall be higher.

This proposition derives from the non-fulfillment of the agent's incentive compatibility condition. However, another sentence derives from it: information asymmetry has a cost for the principal since the prime charged is lower than in the case with perfect information, thus, the benefits obtained by the principal are lower.

Proposition 4. The grey area in Figure 1 determines a space of feasible contracts, however, only one of them maximizes the expected benefit for the principal. This is the contract in which low and great effort indifference curves together with the incentive compatibility restriction are intercepted.

In all the other points of the feasible area, the principal is not maximizing the expected benefit, the points further right and up imply reductions in the principal's benefit, since the prime can always be increased without causing the agent to stop taking part in the contract or choosing the unwanted effort.

[1] Remember that $p(e^A) < p(e^B)$, and, therefore, $[1 - p(e^A)] > [1 - p(e^B)]$, for the reasons, explained under Section 2.2.1, 2, on efforts and occurrence probabilities.

[2] The incentive compatibility restriction graphic for the agent depends on the functional form of its utility function. In this case, utility functions with risk aversion are supposed, therefore the restriction presents a curvature of this type. The double line curve contains all the intersections between $u(e^A)$ and $u(e^B)$ for different utility levels.

2.3. Extensions to the model. There are different modifications on the presented model, that are not formally shown in this work but that are introduced conceptually.

One of the possible extensions consists in incorporating the participation of the state, as an additional principal, that acts as central planner, maximizing the society's joint utility or social utility. In a second extension, the principal does not guarantee the restoration of the whole damage, but just a part, thereof: $[L_C - L_{NI}]$, where L_{NI} is the part of the value of the damage that is not insured. The non-insurable part may depend on the effort made by the agent and, indirectly, on the prime of the environmental insurance contract. In this way, the risk is shared between the principal and the agent, offering greater incentives so as to increase the effort, in order to reduce the environmental accident occurrence probability.

3. Empirical evidence

A case study, based on the analysis of the environmental insurance contract and the regulations, thereof, for a country, in this case, Argentina, is introduced next. The objective is to show some empirical evidence on this topic, so as to be able to compare it with the features of the theoretical models of environmental insurance, proposed above.

3.1. Regulations in force in Argentina. The regulations in force in Argentina, Act No. 25675 and Provisions of the secretariat of environment and sustainable development of the Argentine nation, SAyDS, according to the acronym in Spanish[1], set forth that it is compulsory for those who carry out certain hazardous activities with an environmental complexity level category 2 or 3, medium or high complexity, to take out an insurance policy. The calculation of this parameter is shown in equation (6).

$$NCA = Ru + ER + Ri + Di + Lo + AjSP - AjSGA, \quad (6)$$

where:

- *NCA* is the level of environmental complexity;
- *Ru* is the category of the potentially polluting company. It may take a value of 1, 5 or 10, according to the classification of the activity;
- *ER* is the term that represents effluent and waste generation by the facility. According to the amount and quality of the effluents and gaseous, liquid, solid, or semi-solid wastes, it may take values equal to 0, 1, 3, 4 or 6;
- *Ri* refers to the activity-specific risks that could affect the surrounding population or environment. It takes into account the risk posed by pressure equipment, acoustics, chemical substances, explosion, and fire;
- *Di* is the dimensioning of the facility. It takes into account the number of staff members, the installed capacity, and the surface;
- *Lo* represents the location of the facility. For the quantification thereof, it takes into account municipal zoning: industrial park, exclusive or rural industry, rest of the zones, and its service infrastructure: water, sewerage, gas, and electricity[2];
- *AjSP* is the adjustment by handling of particularly hazardous substances in certain stated amounts;
- *AjSGA* is the adjustment by evidence of an established environmental management system.

According to the environmental complexity level (NCA, according to the acronym in Spanish), companies can be classified into three groups: first category (up to 11 points); second category (from 12 to 25 points); third category (more than 25 points).

The minimum insurable amount of sufficient entity (MMES, according to the Spanish acronym) is also established; this is the minimum insurable amount for recovering the collective incidence environmental damage caused by a polluting accident. The calculation methodology for MMES is shown in equation (7).

$$MMES = Basic\ Amount \cdot V \cdot D, \quad (7)$$

where:

- $Basic\ Amount = NCA^2 \cdot Correlation \cdot Adjustment$ *NCA* is the environmental complexity level;
- *Correlation* is the correlation factor in national currency pesos;
- *Adjustment* is a factor related to variation in the costs of logistics and existing infrastructure for recovery operations that belong to the facility site;
- *V* is the vulnerability factor, described by the following concepts: type of overlying substrate in the saturated area: clay, sand, etc., depth to groundwater, distance from hazardous materials to shallow waters: water surfaces and shores, and environment: residential or commercial, or any protected area. It is calculated as:

[1] For those interested in obtaining further information on the legal framework, the set of Provisions that regulate Section 22 of Act 25675/2002 is detailed next:

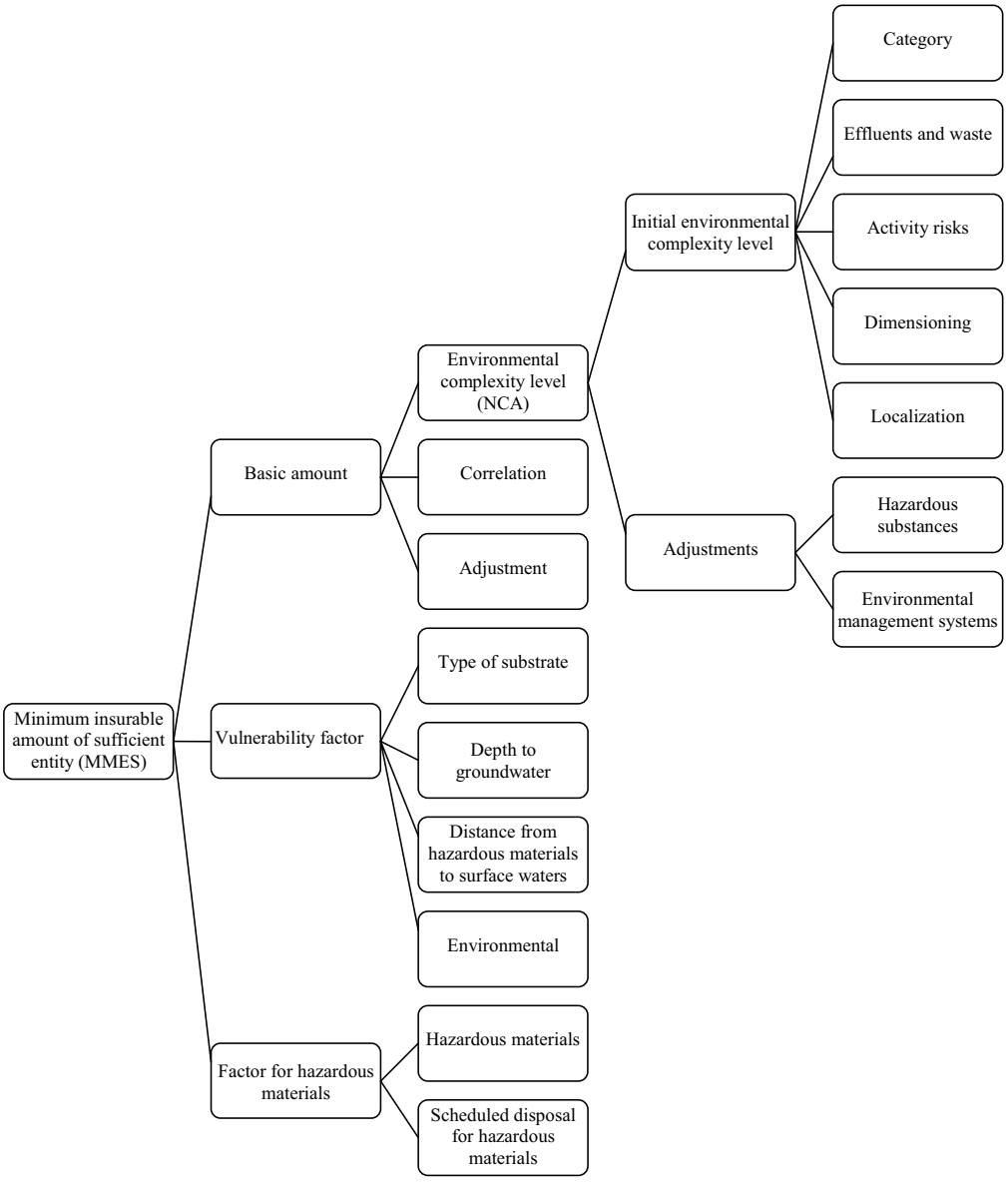
- Provision 177/2007 (SAyDS) and amendments thereto, Provision 303/2007 and 1639/2007 (SAyDS);
- Provision 178/2007 (SAyDS), together with Provision 12/2007 of the secretariat of finances;
- Provision 1973/2007 (SAyDS), together with Provision 98/2007 of the secretariat of finances;
- Provision 1398/2008 (SAyDS).

[2] These first five terms of the polynomial (*Ru* + *ER* + *Ri* + *Di* + *Lo*) make up the so-called initial environmental complexity level.

. $V = \left[1 + \left(Substrate \cdot Depth\ to\ Groundwater\right)\right] +$
$+ Distance\ to\ Water\ Surface + Shore +$
. $+ Environment$;

- D represents the existence of hazardous materials and the scheduled disposal, thereof. It is calculated as: $D = 1 + MP + EP$;
- MP takes into account the volume of hazardous materials existing on the surface, under the surface, and in contact with water or underwater. Each of these types weighed according to a degree of relevance;
- EP represents the scheduled disposal of hazardous materials above permissible levels, whether over the surface, under the surface and/or in contact with water.

In addition, the self-insurance mode is admitted as a valid option adequate to respond for the damage caused to the environment.



Source: Compiled by the authors based on Provisions 1639/2007 and 1398/2008 (SAyDS).

Fig. 2. MMES composition breakdown

Figure 2 shows a diagram with the relation of the concepts introduced in the Provisions of the SAyDS, breaking down the concepts that constitute MMES.

3.2. Current situation of environmental damage surety insurance. Although the described legislation has been in force for several years now, some insurance companies still do not offer this type of coverage and some potentially polluting entities do not decide to take out the policy. According to the national insurance superintendence, at present there is a short list of insurance companies that offer collective incidence environmental damage surety insurance[1], and a reduced

[1] These companies are: Prudencia Compañía Argentina de Seguros S.A.; Escudo Seguros S.A.; Nación Seguros S.A.; Testimonio Compañía de Seguros S.A.; TPC Compañía de Seguros S.A.; El Surco Compañía de Seguros S.A.

number of companies have taken out this policy, out of 35,000 companies that should have it. It is interesting to study which causes explain such behavior: Is there a lack of state controls? Do companies have low aversion to risk and generate self-insurance instead of taking out insurance policies? Are contracting conditions uncertain and, thus, insurance companies do not like to offer this type of insurance? Do insurance companies fail to generate the proper incentives? And, finally, Does contracting environmental insurance policies reduce environmental damage?

4. Discussion of results

On the one hand, Section 2 shows the theoretical models that intend to capture the problem of information asymmetries that exist in insurance contracting, particularly in environmental damages. On the other hand, Section 3 explains the regulations in force in Argentina with regard to environmental insurance contracts and comments on the current market situation. In this Section, a comparison of the different elements of contracts from a theoretical perspective with regard to the empirical evidence is proposed. These derivations are shown in Table 4.

Table 4. Environmental insurance contract comparison from a theoretical and empirical point of view

Elements of the contract	Theoretical perspective	Empirical evidence
Participation of potentially polluting companies	It depends on the fulfillment of the agent's participation condition. This implies that the agent obtains a greater utility if he/she contracts the insurance.	According to the environmental complexity level (>12 points) of the potentially polluting entity, it is compulsory to take out an insurance.
Participation of an environmental insurance offering entity	The principal maximizes his/her benefit to see what are the contracting conditions for the policy (in the basic model the principal determines the prime to be charged).	There is no available information yet to know the determining factors or criteria of the insurance company that makes the environmental surety insurance policy offer.
State participation	In the basic model, the state does not take part. In one of the extensions it takes part as a regulator and maximizer of the social utility.	It is the insured party in environmental surety contracts. It may be the national, provincial, or municipal state as it may correspond, according to ownership of the affected asset.
Prime determination	It depends on the effort, made by the agent, to reduce the occurrence probability of the accident and the value of the environmental damage caused or the amount, insured in one of the extensions.	There is no available information yet on the empirical estimation methodology for primes. This information arises from surveys or interviews to the contract offering party.
Determination of the insurable amount	Through theoretical environmental valuation models, such as restoration costs, contingent valuation, production function variation, hedonic prices, etc. In the second extension, determination of the insurable amount also depends on the effort made by the agent to reduce the occurrence probability of the accident.	Through polynomial formulae that consider variables such as environmental complexity level, vulnerability factors, and hazardous materials, among others. The detail for this calculation can be found in Section 3.1. in this work.
Self-insurance	Self-insurance can be taken out when the agent has no risk aversion – the agent is neutral to risk. Another theoretical alternative is to add a property restriction that shall determine contracting of the insurance if the property of the potentially polluting entity is not enough to cope with restoration of the damage caused.	The law establishes the self-insurance alternative but it does not state under which circumstances. There is no rule, either expressed or implied, excluding this kind of guarantee. However, the constitution matter of the restoration fund is not sufficiently regulated.
Signaling before subscription of the contract (adverse selection)	In order to know the type before the subscription of the contract, the insurance company spends as auditing expenses. According to its observations, the insurance company characterizes the company per type.	Signaling is given through the environmental complexity level and the initial environmental situation. In addition, there are surveys, depending on the insurance company, to be answered for company categorization.
Incentives	The prime depends on the effort made by the agent, a non-observable variable that is intended to be inferred through the amount of effort costs, and on the extent of the damage. On the other hand, the second extension supplies incentives since it does not insure the total amount of damage, but a part thereof.	It does not insure damage in full, thus, the incentive comes from the need to afford part of the recovery amount.
Minimum coverage limit	It is formed by the environmental damage theoretical value in the basic model, and by a part of this in the shared damage model.	It is formed by the minimum insurable amount of sufficient entity, pursuant to Provision 1398/2008. This amount does not arise from a theoretical model but from a polynomial expression with proxy variables to the extent of environmental damage.
Maximum coverage limit	The model does not establish a maximum coverage limit. However, it is possible to think that large amounts cannot be insured.	It exists and it is set in $1,600,000.
Coverage	Total damage coverage provided the insurance company benefits are > 0, except in the shared damage model in which the coverage percentage is <100%.	Part of the damage compensation has an impact on property, determining a dissuasive effect and promoting the necessary preventive actions towards avoiding damage.
Natural resources with coverage	The model does not establish which are the natural resources covered.	Water and soil – not yet air.

Source: Compiled by the authors

According to the made comparisons, it can be stated that the environmental insurance methodology has some very positive aspects, such as the incentive to prevent damage through determination of a minimum insurable amount different from the restoration value and the signaling of the agent type through a rate such as the environmental complexity level. The operability, both for calculation of MMES and NCA through polynomial expressions with highly detailed specified variables, should also be recognized.

On the other hand, there are some elements in the contrast that show great differences in the empirical point of view an in the theoretical one. For example, determination of the insurable amount or participation of the parties to the contract.

Finally, there is the need to continue the empirical analysis of the parties that offer and request environmental insurance, in order to reach a conclusion with regard to pertinence in prime calculation or criteria to decide, to offer the environmental surety insurance on the part of insurance companies.

Conclusions

Taking into account the existing background, some features in environmental insurance policies that provide optimal incentives to agents, so that they shall take actions towards promoting good care practices for the environment, as well as for natural resources, were presented in this research work.

In the introduction, a summary of the major landmarks on the topic of insurance and, in particular, of environmental insurance from an economic point of view, is presented. Then, a conceptual model, based on the theory of information economics (information asymmetries) is shown in order to study the behavior of agents when faced with the optimal incentives in an environmental insurance policy. Under the presented conditions, mainly four proposals arise from this analysis: a constant prime does not offer incentives for the agent to choose the optimal effort; an agent adverse to risk prefers to take out a policy instead of the self-insurance; there is an area inside which the agent's restrictions are satisfied, however, only one of all the feasible contracts maximizes the expected benefit for the principal. Next, an empirical analysis, describing the regulations in force and the current situation of environmental insurance for a particular case, i.e., Argentina, was carried out. Finally, the features, emerging from the theoretical model, were confronted with those observed in the market. Results suggest that there is a great similarity in how some concepts are dealt with, such as the intention of encouraging the agent to make a great effort or the concept to signal it in some way to know its type, while in some others there are substantial differences, as in the methodology used to determine the minimum insurable amount.

This research work presents some progress in the study of environmental insurance problems, a transcendental topic because it is incipient and determinant for outlining public policies that aim at improving the situation with regard to environmental quality.

References

1. Faure, M. (Ed.) (2003). Deterrence, insurability, and compensation in environmental liability, Future developments in the European Union, Springer, Wien, NewYork, Austria.
2. Fernandez de Castro, J. & Tugores Ques, J. (1992). Fundamentos de microeconomía, Segunda edición, McGraw-Hill, Madrid, España.
3. Ferraro, P. (2008). Asymmetric information and contract design for payments for environmental services, *Ecological Economics*, 65, pp. 810-821. Elsevier B.V.
4. Kreps, D. (1995). Curso de teoría microeconómica, McGraw-Hill, Madrid, España.
5. Laffont, J. (1995). Regulation, moral hazard and insurance of environmental risks, *Journal of Public Economics*, 58, pp. 319-336.
6. Mas-Colell, A., Whinston, M., & Green, J. (1995). Microeconomic theory, Oxford University Press.
7. Pesce, G., Vigier, H. & Durán, R. (2009a). Discusiones preliminares sobre métodos de valoración de efectos ambientales. Estudio de un caso, IV Congreso Nacional de Estudiantes de Postgrado en Economía. Available in CD, Ediuns, ISBN 978-987-25102-1-3.
8. Pesce, G., Vigier, H. & Durán, R. (2009a). Revisión crítica de metodologías de valoración de RR.NN. Cuartas Jornadas de la Asociación Argentina Uruguaya de Economía Ecológica y la International Society for Ecological Economics. Available in "Libro de Resúmenes" and in CD, ISBN 978-987-22038-3-2.
9. Rothschild, M. & Stiglitz, J. (1976). Equilibrium in competitive insurance markets: an essay on the economics of imperfect information, The Quarterly Journal of Economics, 90-4, pp. 629-649.
10. Superintendencia de Seguros de la Nación (National Insurance Superintendence), available in: http://www.ssn.gov.ar//Storage/seguroambiental/seguroambiental.html. Date: 10-07-2010.