ENVIRONMENT, MATHEMATICS AND THE BEST SOLUTION TO STOP NATURAL WORLD DESTRUCTION

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ABSTRACT. First, we discuss the use and misuse of mathematics that have been applied to apparently solve environmental problems. We then explore a new kind of environmental cooperation called fusion, in order to analyze the optimal way of using environmental funds, private or public, compulsory or voluntary contributions. We will work with mathematical models, yet our results do not significantly depend on them nor on the parameters chosen. We believe that the specification of models and their particular parameters is the biggest flaw in the application of mathematics in environmental sciences.

KEY WORDS. Solutions to environmental problems, mathematical models, fusion, environmental funds, parameter, Bayesian approach, Principal-Agent method.

MATHEMATICS AND NATURAL ENVIRONMENT

Many environmental studies need mathematical models that are simplified caricatures of a much more complex reality. Models, by themselves, cannot solve problems, but can and should illuminate, at least approximately, what kind of policies should be prioritized. Unfortunately, there are too many studies that wrongly employ mathematics in this setting.

Several statistical studies (usually textbooks) use Bayesian statistics in a rather primitive way, changing prior ideas after observations, therefore, additional assumptions should be made to obtain solid results. A modern Bayesian approach ought to lead toward correct decision making, assigning looses or gains to particular actions, in order to find a fairly optimal solution. To be able to succeed in this task, we need specific models and its assignment of parameters (calibration), more precisely than those postulated in Sterns report, seemingly by the rule of thumb. Nowadays, this approach represents the Nirvana and cannot generate reasonable deci-

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sions. The best we could do is to transport the modern technique of risk measure into environmental sciences, considering various scenarios including the protection against the worst case. This method definitely should be used in environmental studies, yet we need, first, a much better mathematical preparation of environmental scientists, above all in probability theory, and more generally in management of uncertainty.

There are many questions that apparently could be answered with the use mathematics, but cannot be solved due to the flaws in elementary logic (and) or misunderstanding of decision theory. Let us mention the so-called "Hilbertian Program for Earth Sciences" (Clark, et al., 2004) and review some of its questions it, like the strategic question 23: "What is the optimal decomposition of the planetary surface into nature reserves and managed areas?" To reach desired optimality one needs to have preference order between outcomes. We believe that in this particular case, establishing preferences is simply impossible, and the problem is idly posted. Some other question: "What is the current capacity of the Earth?" reminds the famous old discussion on how many angels can dance on the head of a pin. In our opinion, formulating such a program does not help to solve whatever environmental problem we are facing. On the opposite, it deviates from the environmental studies and policies worth to develop and apply.

Mathematical and physical language should not be used without a deep understanding of the theory from which their concepts are borrowed. Uncertainty principle or the quantum physics cannot be used carelessly just to make the audience think that deep thoughts are behind. Nonetheless, these days, the use of mathematical words without its proper sustain enters many different fields, for example, philosophy, and the best reference on how it can end is Sokal's book *Fashionable Nonsense*. On the other hand, the use of extremely abstract mathematics, like category theory (John C. Baes) within environmental studies becomes no more than a plain joke.

ENVIRONMENT AND FINANCIAL MARKETS

There have been many attempts to use financial markets to combat or diminish environmental deterioration. Among the most significant are the following:

1. Emission trading (known as cap-and-trade) related to permits to pollute.
2. Economic evaluation based on "willingness to pay" known as full "cost-benefit" analysis.
3. Establishment of property rights, i.e., the privatization of nature.
4. Valuing environment through contingent valuation (Hanemann, 1994).

Anyhow, none of the mentioned above has produced desirable effects.

1. The main deficiency of "permits to pollute" approach is that it does not stimulate any cooperation. If someone finds new method to capture carbon (just to give one example), there is no reason to believe that he or she would share this invention with others instead of profiting by selling permits. Beside, it leads to a wild market with strong governmental intervention, for example, assigning initial quota called "*grandparent effect*."
2. Full economical analysis needs very precise models, yet natural phenomena are far too complex and depend on too many variables to be fully understood or measured. Mark Sagoff rightly stressed that "(...) the immense effort economists have invested over decades in trying to measure the benefits of environmental resources and services has resulted and can result only in confusion" (Sagoff, 2004).
3. Establishing property rights that require institutional arrangements and procedures that are difficult to accomplish, should not be proposed as a solution to the "tragedy of the commons." Natural resources are hard to privatize. Even dealing with deforestation (this being a dilemma that mostly affects developing countries), the attempt to set property rights encounters increasing social problems rather hard to solve.
4. The Contingent Valuation Method (CVM) was used to estimate economic values of all kinds of ecosystems and environmental commodities, by asking how much one would be willing to pay for a specific good. Unfortunately, the answers were closely related to the educational level of people involved and the order of questions asked.

Although the comprehensive conservation of the biological diversity requires a strategy that goes beyond cost-benefit analysis, the monetary valuation can play a supportive role in environmental policy, but its multiple practical and normative problems have to be considered when using such a method, above all in developing countries, where people are too poor to think about environmental degradation. As Philip E. Graves wrote, "to the extent that we value public goods, we also realize that getting extra income to buy them will accomplish nothing" (Graves, 2003). It was A. Fitzsimmons who, in his controversial book *Defending Illusions*, pointed out the possibility of creating markets on environmental topics. He assumed that the Wetland Protection Certificates could be bought and sold, and that a market may be established by the US Congress (1999).

We propose the use of Principal Agent methodology and the creation of markets on certificates of environmental improvements. Market on good certificates is unable (and we do not pretend to obtain any approximation) to valuate environmental goods. To be able to generate market one should trade as well bad certificates awarding environmentally harmful actions, but this kind of certificates are clearly unacceptable. The creation of markets is the natural answer to many problems in finance, for instance, we are not able to estimate the mean return on assets, but creation of liquid financial market with many derivative products makes this problem irrelevant. Trying to involve the environment in the so-called financial innovation spiral we, in a sense, follow the ideas of R. Merton and Zvi Bodie expressed in their book *Fundamentals of Corporate Finance* (2005).

Our method does not pretend to price environment by endowing it with market value. What we propose is the direct market out of *environmental improvements*, always when a high reliability measurement of actual state could be ensured, for example, the number of wind turbines. The "conditional carrot" approach using the Principal-Agent methodology [1] might be the only way to deal with the most serious environmental crisis. In fact, this approach has been already under way in combating pollution, like opening of high-occupancy vehicle lines or promoting hybrids. However, it poses a different optimization problem since the initial costumer's decision remains stable over time.

On the whole, the Principal-Agent method (nature being the Principal *represented by a financial institution*) aims at creating new investment opportunities that will stimulate economic development of the region, benefit local communities and protect the wildlife. Agent could be anyone who buys the certificate or, in situations involving reforestation, these certificates could be given free of charge to the inhabitants of a community. Participation means the ownership of corresponding certificates. It also offers transparency in handling conservation funds that may be created from taxes, voluntary contributions, or offsetting environmentally harmful actions. It can be taken for granted that the main problem of any environmental decision is not how to impose additional taxes, but how to use the collected money wisely and effectively. The fund creation offers a more efficient way to improve and protect the environment than spending millions of dollars in organizing panels of experts who conclude (with fuzzy estimation of probabilities) that degradation is caused by human activities.

Different approach with the use of the Principal–Agent method has been thought-out by Damato and Franckx (2003). They wrote: "We have considered there the regulation of a (private or public) agent by an EPA (Environmental Protection Agency). This EPA is constrained to basing its incentive scheme (both rewards and punishments) on environmental performance, and allocates funds to alternative projects with environmental benefits. The private agent can allocate its effort either to environmental protection or to its core task [2]." However, our approach does not need precise specification of parameters, as the quoted study requires.

The precise optimality of such certificates—*Principal optimization problem*—depends on the given models. After using this method for a while, we can consider more exact models to get precise optimality stemming from the strict application of the Principal-Agent method. It is worth to bear in mind that in modern finance applications often anticipate theories, models and theorems. Usual cost-benefits analysis compares Nash competitive equilibria with collusive ones. The well-known mismatch between these two (depending heavily on the parameters chosen) does not have an easy solution, and is linked to coalition creation and eventual renegotiation through the theory of repeated games [3].

The good news is that our project can start with the issue of *any* good environmental certificate. Instead of diffuse promises of cutting pollution that could put poor countries (if compromised) back to some dark age, we should consider bona fide cooperation, which can be accomplished by properly using the Principal–Agent methodology.

In our previous studies we analyzed the problem of one agent and cooperation problems in some models as well. In this study we are able to give robust answers in the sense that our conclusions are independent of parameters of the chosen model.

OUR GOLDEN IDEA AND THE MATHEMATICS BEHIND IT

Our present goal is to prove that cooperation is worthy in a very popular geometric Brownian motion model.

First, let us explain what do we mean by being worthy in a very simple deterministic model, comparing fusion solution against collusive one. We call fusion the case when one agent can make improvements in other agent's domain. Assume that a Principal, meaning some financial institution, emits certificate that pays

$$S - (X_{(1)} + X_{(2)})^2$$

being $X_{(1)}$, $X_{(2)}$ pollution levels in time 1, as is the fund. For simplicity sake we chose 1 as a time horizon. We assume identical agents.

Set,

$$\Delta = X_{(1)} + X_{(2)}$$

We assume that

$$S - \frac{\Delta^2}{3} > 0$$

So with her or his optimal solution, the Agent will not fall in negative award. We choose quadratic function for the cost of abatement of pollutants u, therefore collusive optimal solution consists in minimization of

$$(\Delta - 2u)^2 + 2u^2$$

From there optimal

$$u^* = \frac{\Delta}{3}$$

The total pollution level is

$$\frac{1}{3}\Delta$$

Fusion optimal solution consists in minimization of

$$(\Delta - Au)^2 + u^2$$

(note: we will call A cooperation factor)
Optimal,

$$\widetilde{u}^* = \frac{\Delta A}{A^2 + 1}$$

and pollution level for fusion will be smaller than in collusive case

$$\text{if } A > \sqrt{2}$$

independently of Δ. Greater cooperation factor means larger development of technology and eventual transfer of it from one Agent to another. As we shall see, the same cooperation factor will appear in stochastic model when Agents will minimize in both collusive and fusion case the expected value of

$$(X_{(1)} + X_{(2)})^2 + \text{cost of abatement}$$

GEOMETRIC BROWNIAN MOTION (GBM) MODEL

We consider stochastic models based on Brownian motion as sources of uncertainty. Brownian motion also called "Weiner process" (after Norbert Weiner) is present in all branches of science (randomness involved) as a building block for more complicated and adequate models particularly in quantitative finance. Practically all stochastic models can be constructed from Brownian motion with hundreds of book and thousands articles on this subject. We believe that Brownian motion should constitute a fundamental part of modeling environmental changes. Brownian motion is a collection of random variables W(*) (* represents any time value).

W(0) = 0 (note: we use modern notation for F(*) instead of F(t) than can be interpreted as the value of the function at time t.)

W(*) has independent increments. It means that W(t) - W(s), for t greater than s is independent of the process W(*) up to time s. W(t) - W(s) ~N(0,t - s) (normal distribution with mean 0 and variance t - s). Additionally we assume the continuity. It means that as we see (for any fixed random element w,W(w) as a time function, it is continuous. A very popular model called geometric Brownian motion is defined as

$$S\ (t) = xe^{\sigma W(t) + (\mu - \frac{1}{2}\sigma^2)t}$$

with expectation

$$E(S(t)) = xe^{\mu t}$$

It is standard model to represent the value of financial assets. S(t) satisfies the following stochastic differential equation

$$dS(t) = \sigma S(t)dW(t) + \mu S(t)dt$$

that should read as

$$S(t) = x + \sigma \int_0^t S(u)dW(u) + \mu \int_0^t S(u)du$$

The second integral is just standard Riemann, while the first is Ito integral and can be seen as a limit (in proper sense) of

$$\sum_{i=0}^{n_k - 1} S\ (t_i^k)\ (W\ (t_{i+1}^k) - W\ (t_i^k))$$

t_i^k represents partition points of the interval [0,t] and

$$\Delta_k = \max\ (t_{i+1}^k - t_i^k)$$

tends to zero.

THE MODEL

Assume that pollution levels without cleaning actions increase as

$$dX_i(t) = \alpha X_i(t) + \beta X_i(t)dW_i(t)$$

And with positive actions become

$$dX_i(t) = \alpha X_i(t) + \beta X_i(t)dW_i(t) - u_i(t)$$

i =1,2 and instantaneous cost of improvement

$$u_i(t)$$

We assume that W_1, W_2 are independent. In the case of fusion

$$d(X_1(t) + X_1(t)) = \alpha(X_1(t) + X_1(t)) + \beta X_1(t)dW_1(t) + \beta X_2(t)dW_2(t) - Au(t)$$

With the cost of improvements

$$u^2(t)$$

Once again we call A cooperation factor. Using model technique of stochastic backward differential equations (BSDE) we can prove that with the cooperation factor greater than √2.

Exactly as before, fusion generates lower level of total pollutions.

$$E(X_1 + X_2), \text{ for } A > \sqrt{2}$$

Another advanced technique can show that

$$\text{(collusive) } X_1(t) + X_2(t) < \tilde{X}_1(t) + \tilde{X}_2(t) \text{ (fusion)}$$

Therefore certificates (payments to Agents) of the form

$$S - (X_1 + X_2)^2$$

will stimulate cooperation. Total cooperation could signify A = 2 and would produce much better results and more gains for Agents. The optimization method (BSDE) can be applied to more general case of unequal Agents and for W(1), W(2) with some dependent structure. Another technique applied to minimization of

$$\int_0^1 (X_1(t) + X_2(t))^2 \, dt$$

produces similar results with the help of numerical methods.

Also in the variety of different models fusion produces better results with A smaller than 2 (cf. Szatzschneider, Kwiatkowska, 2011).

NOTES

1 See: Laffont J.J. and Martimort D., *The Theory of Incentives: The Principal Agent M*odel, Princeton: Princeton University Press, 2002.

2 Franckx Laurent and Alessio DAmato, "Environmental policy as a multi-task principal-agent problem," *Energy, Transport and Environment Working Papers*, 2003.

3 Ray R. ,"Economic value added: theory, evidence, a missing link", 2001.

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