Reactive vs Proactive Corporate Environmental Management: A System Dynamics Learning Environment

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Introduction

New realities are leading an increasing number of businesses to discard their old managerial perspectives and practices with regard to the natural environment. Among them, a major role is played by increasing pressure from the public, more stringent environmental regulation, threatening civil and criminal enforcement measures, changes in consumer preferences, new business opportunities and the development of cleaner production technologies. Tomer (1992) stresses the role of some of these factors in the stimulus to the development of new managerial approaches, specially in the recognition of environmental management as an important functional area, that is taking place alongside traditional areas such as marketing, finance, R&D, and manufacturing. In support to this development, courses on environmental management and policy are starting to be offered at business schools, and firms are already integrating environmental goals within their overall corporate strategy.

Of special concern regarding environmental management is the way the firm deals with the pollution it generates. Traditionally, firms have relied on the implementation of pollution control devices in response to regulations, a practice referred as *reactive* or mandated; more recently, a *proactive* or anticipatory practice is starting to take place in several firms, with a special emphasis being given to the implementation of cleaner production strategies and pollution prevention actions (Gabel & Sinclair-Desgagné,1992a,1992b,,1993; UNEP, 1993, 1994b, 1995; Freeman, 1995).

Higher economic and environmental performances revealed in most case-studies dealing with proactive practices, has led to their encouragement by organizations such as the UNEP and the US EPA, while calling for a deeper understanding of their effects. Also, many corporations are viewing the adoption of environmental management procedures as a way to find profitable new business oportunities and many are even requiring the adoption of similar codes of practice by their partners in the business chain. (Gabel, 1995; Corbett & Van Wassenhove,1995). Literature in the field stresses the need for an holistic view incorporating economic, environmental, social and behavioural aspects. The lack of such view, associated with limitations of managers mental models in the processing of relevant information involved in environmental management decision making, are often referred as causes for misperception of major effects and interactions, and lower performance.

To support learning in this field, a system dynamics based Interactive Learning Environment (ILE) was developed in Powersim'. The game is intended to be used in undergraduate courses of environmental management, with the student playing the role of the firm manager. A special emphasis is given to the overall effects associated with reactive or proactive practices, concerning both the firm and the society/environment in which it is integrated.

The Firm and the Environment

In the neoclassical model, the firm is assumed to have perfect knowledge of alternative courses of action, and to choose the one that maximizes its profit. The firm's behaviour can be seen as an outcome of the economic incentives impinging uppon it, i.e., of the product and resource markets in which it participates, and of instruments imposed by the authorities seeking to regulate it.

The problem of pollution is seen as a market failure, a *negative externality*, resulting from the use of collectively owned resources (rivers, lakes, atmosphere,...) as a source of raw materials or as site for disposal of by-products from the productive processes. In order to deal with it, the solutions advocated have been to change property rights and/or to implement command and control or fiscal and economic instruments, to attain the socially optimal level of pollution, namely through the internalization of the social costs of pollution in the manager's decision making process, conducting profit-maximizing firms to a socially optimal behaviour.

Due to the realities faced nowadays by the firm, its behaviour can be no longer fully explained on the basis of economic incentives, and other issues need to be taken into account in environmental management decision making process. Tomer (1992) proposes a conceptual extension of the neoclassical model, refered to as a socio-economic model of the firm, which intends to explain strategies that go beyond the neoclassic objective of profit maximization, and acknowledges explicitly the importance of other incentives confronting management decision making, such as environmental opportunities, internal organizational capabilities, societal "macro" influence, "micro" social influences of extra-firm institutions and infrastructures, and other regulatory influences.

The System Dynamics Model underlying the ILE

The model underlying the developed ILE reflects generic interactions, being its conceptualization largely based on the socio-economic model of the firm previously referred, integrating some of the influences referred by Tomer. The elements included in the game were restricted to allow a more effective understanding of its learning objectives and giving the player the perception of major interacting factors and effects from his decisions without diverging his attention with issues of smaller relevance or "noise", as discussed by Greenblat (1989) and Lane (1995).

Major Sectors and Causal Relations

The generic model is divided into four main sectors, linked by major interactions, as presented in figure 1. The firm gives an input of pollution to the environment and of goods to society. The environment, as a result from the inputs of pollution and its own regeneration capacity presents an environmental quality that will affect environmental regulation, society´s concern for environmental issues, and the net growth of population through short and long term effects. Environmental regulation incentivates the firm to behave towards a desired environmental quality. Finally, society shows through demand its needs and/or desires for the firms products, with a relative influence from acquired concern for environmental issues.

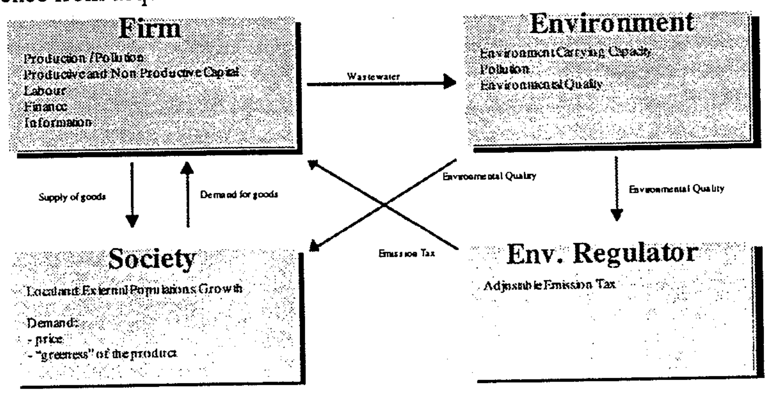

Figure 1 - Major sectors and respective interactions of the system dynamics model underlying the developed ILE.

Endogenous Strategies and Associated Behaviour

The model also considers two endogenous strategies, adressing reactive and proactive management. These additional structures use the information generated by the model to support alternative heuristics for decision making. Each of them adresses decisions concerning investments in the production process, pollution control and/or payment of environmental taxes, environmental training and information/communications.

The results from simulation of the two strategies reveal the expected behaviour. By adopting a reactive strategy, the firm performs better in the short term, but reaches sooner a limit in capacity increase, due to the high costs associated with regulation compliance and/or with increasing investments in wastewater treatment facilities. On the other hand, with a proactive strategy, based in structural changes in the productive process, the firm is able to deal simultaneously with the problem of reducing pollution and maintaining growth, as seen in figure 2.

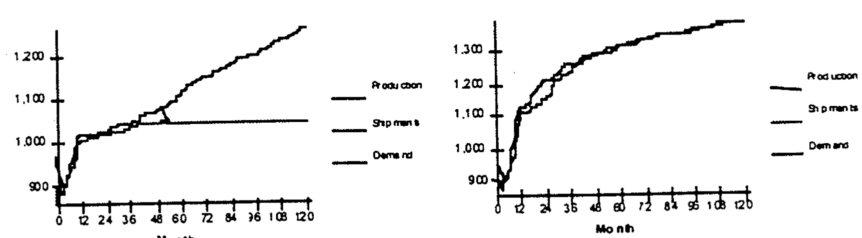

Figure 2 - Generic behaviour of the production rate, shipments rate and total demand, in simulations involving the reactive (first graph) and proactive (second graph) management strategies.

The results reveal the generic behaviour described by UNEP (1995), namely the economic advantages of a proactive approach. They also agree with several case-studies refered in the literature (US EPA 1991,1992; UNEP; 1993,1994,1995; Vold, 1994; Freeman, 1995), in which investments in cleaner production not only bring the firm a similar environmental performance but have a payback period, although variable according to the type of investment. On the other hand, and also as referred by UNEP (1995), investments in pollution control and emission taxes turn to be a financial burden, bringing additional costs to the firm that are never paid back. Total compliance costs of the proactive managed firm remain below those of the reactive firm, even though the first one is producing and selling a higher amount of goods. A cost advantage is clearly presented by the proactive firm regarding regulation compliance and pollution abatement, as referred by Hart & Hauja (1996) in their survey on empirical case studies.

In what concerns the environmental performance of each strategy, the reactive firm presents higher pollution loads per unit of good produced than the proactive one. This behaviour is directly related with source reduction achieved by pollution prevention and cleaner production processes by the proactive firm, while the reactive one only reduces its emissions by pollution control facilities. Higher efficiency in reducing emissions from the productive process is thus achieved by the proactive firm. Directly associated with this, management of the proactive firm leads to the achievement of a higher environmental quality in the region where the firm is placed.

Model Validation

Validation of system dynamics models is described by Barlas (1994) as a process involving both formal/quantitative tools and informal/qualitative ones, in order to establish confidence in the usefullness of the model with respect to its purpose. Direct structure tests were performed during model conceptualization and development. Structure-oriented behaviour tests (extreme condition tests and sensitivity analysis) were held afterwards to assess the validity of the model structure indirectly. The observed behaviour revealed the plausability of the results from simulation against knowledge/anticipation of what would happen in real life; alternative parameter values that could cause the model to fail in behaviour tests previously passed were not found, increasing confidence in the model structure (Forrester & Senge, 1980). The model revealed to be particularly robust regarding the tests to which it was submitted, and was considered valid, and suitable to the development of an ILE uppon it.

The System Dynamics Based ILE

Gagné (1995) describes learning as involving a set of internal processes, themselves unconscious and automatic, which can be facilitated by external stimulation. The author describes several events associated with each type of learning process, and strategies that can be used in the design of instructional material to deliberately influence each of them. Specifically for the case of computer aided instruction, techniques to enhance the learning potential of computer based learning environments are disccussed by several authors (Hannafin & Peck,1991; Lane,1995; Isaacs & Senge,1994).

The developed ILE is intended to be used in the context of environmental management courses at an undergraduate level. After watching the decisions/effects from the endogenous strategies, the player assumes the role of manager of a firm, being asked to take decisions regarding the variables concerning the endogenous strategies. With the experience from gaming, the student is expected to get insight on major structural/behavioural relationships adressed by the ILE, which will allow him to increase his performance on the environmental manager role.

Regarding the design of the ILE interface, the need for stimulation of Gagné´s (1995) learning processes such as expectancy, perception, working storage, semantic encoding, long-term storage, retrieval and generalizing was a concern. A major learning advantage regards its capability for effective double-loop learning, due to the potential associated with playing in Powersim´s strategic or operational modes, and the incorporation of two endogenous strategies that can be switched on/off according to the players will.

As referred by Isaacs & Senge (1994), the type of learning required for fundamental improvement involves discovering how established policies are creating problems to the organization and inventing new policies to improve behaviour. In this sense, the ILE presents a clear learning potential, since the player is allowed to watch decisions/effects from generic established policies, try successively his own policies in a strategic mode observing their results and improving his skills on dealing with the problem, and finaly, accepting the set of decisions that improves behaviour, in operational mode (see figure 2).

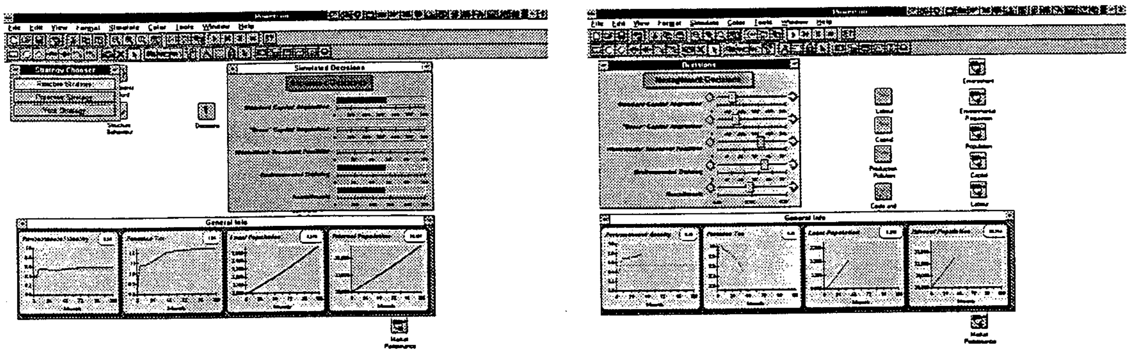

Figure 2 - Double-loop learning is supported by the design of the developped ILE: in the first case, the player watches decisions/effects of an endogenous strategy; in the second one, the player takes his decisions in strategic or operational mode.

Current Work

Extensive testing, validation and evaluation of the developed ILE will be done within the context of environmental management courses at the New University of Lisbon. Results from the use of the ILE will be analyzed with a special concern for the fullfillment of its learning objectives, namely through evaluation of performance and concepts transference.

Simultaneously, improvements in the presented version of the ILE are also being undertaken, concerning the development of an improved structure/behaviour window based on multimedia features. The idea is to reflect the relationships between existing structure and resulting behaviour through the use of video images associated to the key variables values, so that causal effect links can be better perceived by the player.

Model enhancements are also in course to develop a network game, in which several firms located in the same region contribute together for its environmental quality, and share a common market. Players will take the role of managers of each firm, competing in the market (e.g oligopolistic market), so that a more realistic learning experience is performed. Another development envisages to consider an assymetric game, where the environmental regulator is himself a player that can use different types of regulatory and economic instruments to incentive the firms, such as emission standards, emission taxes, and tradeable emission permits. Experience gained from theoretical work on the subject with system dynamics models by Antunes et al. (1996) will be considered for this purpose.

Aknowledgements

Funding for this work was partially supported by the PhD scholarship BD/5469/95 attributed by Program PRAXIS XXI of JNICT to the first author.

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