THE IMPACT OF ENVIRONMENTAL POLICY IN FIRMS BEHAVIOR: A SYSTEM DYNAMICS APPROACH

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EXTENDED ABSTRACT

Introduction

Pollution control policy has relied on the use of comand and control (e.g. emission standards) and market based (e.g. emission taxes or permits) instruments, to promote the attainement of established environmental quality objectives. In the design of such instruments a process-oriented approach, directed to the control of emissions in production processes has traditionally been followed. More recently, the adoption of a product-oriented approach, where the environmental performance of products is controlled, namely through a life-cycle analysis, has been viewed as an alternative and a complement to traditional environmental policy instruments (Santos & Antunes, 1993).

The objective of this research is to gain understanding about the effects of product-oriented as an alternative to process-oriented environmental policy on markets behavior and its consequences in terms of economic efficiency, equity, environmental emissions and damage, efficciency of the pollution control policy, and R&D strategies. In order to achieve this objective, a comparative analysis of the behavior of oligopolistic firms in the presence of process oriented environmental policy instruments, such as emission standards, emission taxes and tradable discharge permits, as well of a product oriented instrument, such as a product tax was performed.

The analysis of a product based environmental policy instrument, requires however the adoption of a product-life cycle approach, considering all the stages for the production and consumption of a final product. Even for traditional process oriented instruments, a product life-cycle analysis is interesting, since it allows taking into account the effects in the production chain, besides the effects in the final product market (the only ones usually studied in economic litterature).

Due to the dynamic nature of the problem and the complexity of the system to be studied, a system dynamics modelling approach was adopted to develop a conceptual framework to achieve the above mentioned objectives. The adoption of a dynamic simulation approach to this problem is very useful since it allows the simultaneous analysis of a considerable number of different effects and their results in terms of dynamic behavior patterns, allowing the understanding of the trade-offs associated with the different environmental policy instruments.

The developed model simulates a duoplolistic market in terms of firms in the production chain and final product market behavior, and also the effects in environmental quality. The model also allows the testing of different R&D strategies that can be adopted by the firms when faced with environmental policy. This system dynamics model is a rich as a learning tool that can be used to gain understanding about markets behavior when faced with different environmental policy instruments.

This paper presents a description of the conceptual model, some of the results obtained and the validation tests performed. Relevant conclusions about the effects of the different environmental policy instruments and policy recomendations can be extracted from the behavior patterns observed in the simulations performed.

Description of Model

The model is organized in sectors, including the manufacturing of the products, market related sectors, environmental sectors and R&D. A detailed descrition of the model in presented in Antunes*et al*, (1995).

As stated above, a life-cycle approach was adopted, considering three stages in the production chain: extraction of raw materials, manufacture of an intermediate product and manufacture of the final product. It was assumed that two final products were produced, each incorporating one intermediate product, which were produced using one raw material each.

A duopolistic market was modeled, based on the Cournot model of duopoly (described for instance in Varian, 1994) considering two desired production sectors, one for each company, where a firm decides its production strategy, based on the demand function, production costs, and on the expectations that it has about the other company. Each time step, each firm adjusts its forecast of the other company production decision according with its sales in the market.

A quadratic total production cost function on produced quantity was adopted for each company. However, the production costs are specifically dependent on the firm's environmental costs and on the cost of the corresponding intermediate products.

In the demand sector of the model the two final products are considered perfect substitutes, and so a joint linear demand curve was assumed. The price, transactioned quantity and consumer surplus are instantaneous indicators of the behavior of the system that are computed. The accumulated consumer surplus and transactioned quantity are also calculated, in order to allow the comparison of the cumulative results obtained with different environmental policies.

Environmental policy can be implemented either by the establishment of an emission standard, an emission tax, a tradable emissions permits scheme or a product tax. The amount of treated emissions for each product is a function of the most stringent environmental policy instrument that is being applied at the moment and of the best available abatement technology, which constraints the maximum treatment level attainable in each process. The costs and other indicators associated with the environmental policy for each production chain are evaluated. The average environmental costs associated with each product are calculated as the sum of the treatment cost, the emission tax cost, the permits net cost and the product tax cost, per unit produced.

The level of environmental pollution is calculated as a function of the emissions generated by both production chains, minus the regeneration that occurs in the environmental system. Environmental damage is computed assuming that there is an average pollution damage associated with a given value of environmental pollution.

The Global Efficiency of the system is computed by the sum of the accumulated profit of the producers of each final product, the accumulated profit reductions in the intermediate products and raw materials stages, due to environmental costs, the accumulated consumer surplus and the accumulated emission and product tax revenues, minus the environmental damage.

Each firm producing the final products can reduce its environmental costs, by R&D, adopting three different and complementary strategies: (1) invest in abatement technology in order to have more efficient abatement processes, decreasing emission treatment costs per treated unit, (2) invest in cleaner technology, in order to reduce the emission factors associated with the production processes and (3) invest in improvements in product design in order to reduce the amount of intermediate products incorporated in the final products. The proportion of investment that is directed to each of these areas is a decision variable.

The amount of reduction achieved with each innovation is variable and is a non-monotonic decreasing function of innovations previously attained. The level of reduction achieved in each of these areas is then used to calculate new values for treatment costs, emissions generated and resources consumed in each production chain in the corresponding sectors.

The major decision variables of the model are related with the adoption of an environmental policy (establishing a value for the emission standard, or an emission or product tax, or issuing a given number of tradable discharge permits), the emission factors associated with each process and the allocation of R&D investment effort among the three mentioned alternative strategies. Other decisions are related namely with the input-output coefficients in the production chains, the production cost functions coefficients, the demand function coefficients and the treatment cost functions coefficients. The regeneration rate is also an important variable for the analysis of the environmental efficacy of the adopted environmental policy.

The impact of the different decisions in the model behaviour is analysed by some impact variables, which include accumulators and instantaneous indicators of system's performance. The main accumulated impact variables are the consumer surplus, profits and environmental damage. Other accumulated variables of interest are the accumulated profit variation for each producer of raw materials or intermediate products, the accumulated R&D investment for each firm, the accumulated treatment costs and tax revenues and the cumulative transactioned quantity.

The price of the final products and the emissions per unit produced are important indicators of systems performance. Other indicators are the values of the emission factors and input-output coefficients, which, with the treatment costs, show the efficacy of the R&D policy of the firms.

In order to build confidence in the model's results, and to test the impact of some of the assumptions made on the major policy recommendations extracted from the model, a series of tests, including extensive sensitivity analysis on some of these parameters, was performed (the sensitivity analysis of the model is described in Santos *et al*, 1995).

Conclusions

The results obtained with this model show the potential for the application of system dynamics for the analysis of environmental policy and its impact on firms behavior, allowing the dynamic analysis of the behaviour patterns that arise from the feedback interaction of many variables, the evaluation of steady-state conditions and accumulated results, and the analysis of trade-offs between alternative policy instruments.

The model is a rich learning tool that allows the test of different policy options, nalmely the trade-offs between the several instruments, the analysis of different forms of implementation of an instrument (ex. different forms of emission standards, different rules for the initial allocation of emission permits, different criteria for the implementation of a product tax), as well as the comparison of constant vs progressive (in time) implementation of the intruments.

The policy analysis performed with the model allowed the confirmation of the advantages of economic instruments when compared with comand and control approaches. The potential for the application of product oriented economic instruments, in this case a product tax, was also stressed. The major problem associated with this type of instrument is the difficulty to control the level of pollution in the initial stages, due to the low values for the unit tax that had to be assumed in the begining of the simulation in order to ensure the survival of the firms. Being so, this instrument does not seem to be suitable for the achievement of short term environmental policy targets, although it leads to better environmental performance and higher efficiency in the long run.

The advantages for the market of the progressive implementation of emission and product taxes were also demonstrated, although the obtained results also showed the increased difficulties to control environmental damage that are associated with this approach.

The analysis of the effects of the firms' R&D strategies in terms of market competitiveness and environmental quality, under the different environmental policy instruments was also performed. The investment in R&D leads to a general increase in global efficiency, with a significative decrease in environmental damage for emission and product taxes which are the instruments where the accumulated investments in R&D are higher, leading to a better environmental performance of the products in the long run. In the presence of an R&D strategy by the firms in the production chain, the policy-maker must adopt different strategies to ensure the attainment of pre-defined levels of environmental damage, for the different policy instruments.

The model also allowed to show that the implementation of more stringent environmental standards brings competitive advantages to the firms and products that have a better environmental performance in their life-cycle, contradicting the usual assertion that environmental policy always has a negative impact in the markets and in the firms. This can be an important conclusion that can be used to show to the managers that in some situations the adoption of environmental regulations can contribute to increase their profits, instead of being viewed always as an extra burden to the firm.

It was also shown that emission standards are the instrument that implies a more significative inversion in the market leadership, caused by environmental policy, between two different firms with production costs and environmental performance varying inversely, which is also an interesting conclusion contradicting the usual assertion that an emissions tax, for example, inducing higher costs in polluting firms have a larger effect in firms competitiveness than comand and control approaches. In fact, the efficiency gains provided by the adoption of an economic based approach, attenuate the impact of the taxes on the market.

Although policies directed only for one of the two considered chains create an unfair allocation of costs and imply a much higher environmental damage than in the same policies directed for both chains, the model also showed that, in global terms, it is more efficient to act than (to) do nothing.

Future work includes the development of a case study, based on existing data about production chains, market and environmental performance of two different perfect substitute products.

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