UNIVERSIDADE FEDERAL
DO RIO DE JANEIRO

INSTITUTO DE ECONOMIA

Integrating evolutionary and ecological economics: a dynamic analysis of enviromental concern and innovation in Brazilian firms

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Textos para Discussão

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Impressão: *IE - UFRJ*

Ficha catalográfica

LUSTOSA, Maria Cecília J.

Integrating evolutionary and ecological economics: a dynamic analysis of enviromental concern and innovation in Brazilian firms. / Maria Cecília J. Lustosa, Carlos Eduardo F. Young. - Rio de Janeiro: UFRJ - Instituto de Economia, 2000.

29 p.; 21 cm. - (Texto para Discussão. IE/UFRJ; nº 447)

1. Inovações Tecnológicas. 2. Firmas Industriais. 3. Economia Ambiental. I. Young, Carlos Eduardo F. II. Título. III. Série.

O Programa Editorial do IE/UFRJ (sucessor dos Programas Editoriais do IEI e da FEA/UFRJ), através das séries "TEXTOS PARA DISCUSSÃO", "TEXTOS DIDÁTICOS" e "DOCUMENTOS", publica artigos, ensaios, material de apoio aos cursos de graduação e pós-graduação e resultados de pesquisas produzidos por seu corpo docente.

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SUMÁRIO

Abstract

The objective of this paper is to examine the behaviour of industrial firms in terms of environmentally related innovations. The main assumption is that the firm decisions concerning environmental restrictions can be studied from an evolutionary perspective, which emphasizes the dynamic aspects of the innovation process. Therefore, the analysis is centred on the relationship between technology and the environment, and the motivations for the development and diffusion of innovations among the economic sectors. The theoretical conclusions were then tested using data from an industrial survey for the state of São Paulo, which concentrates around half of the Brazilian industrial production. The main results were: (i) the highest degree of understanding environmental considerations as business opportunities was demonstrated by firms with global interests and, independently of being owned by nationals or foreigners, they do not foresee market losses caused by environmental consequences of their actions; (ii) the firms which modify the most their production processes for environmental reasons are the ones which invest the most in R&D; (iii) the strategy of environmental preservation as a way to induce innovation is much more present in companies which attribute higher importance to their own R&D department.

1. Introduction

The debate on economic growth has always been intense in the economic literature. A new dimension of this debate was introduced in the late 1960s, with the question of whether to accelerate or not economic growth given the rising pressure on natural resources. Technology was considered as static, and the faster the economic growth, the higher would be the deterioration and exhaustion of the Earth's resources[1]. In the 1970s there was an increasing diffusion of environmental policies, which privileged end-of-pipe solutions. Only in the 1980s it became more widely accepted that technological patterns would necessarily have to be changed to deal with environmental problems.

The question was no more whether to have economic growth or not, but *which kind* of economic growth. It was quite clear that the dominant technologies resulted in unprecedented levels of pressure on the environment, and technological changes were the key to revert the process. Therefore, new dimensions were added to the debate: the generation of technological knowledge, and how to expand the diffusion of these innovations in the production and consumption chains.

The industrial sector became an increasing target of regulations and restrictions, given the high degree of environmental impacts in the life cycle of its output. Because of the financial costs derived from legal standards (current and capital costs for "cleaning" the process, or levies and penalties, in the case of non-compliance), environmental concerns are seen by many businessmen, policy makers and academic economists as an additional cost for the industry, reducing its competitiveness.

However, it is important to examine the micro roots of this problem. The firm/industrial sectors are responsible for pollution or other externalities because of the adopted technology (not only the production technique but also the organisation of the productive process, the environmental performance of the final product and its disposal, etc.). Hence, the firm/sector capacity to generate and adopt *environmentally friendly technologies* is determinant for a better environmental performance.

The innovative capacity of the firm depends on internal and external factors. The internal factors include specific competences to solve problems, its absorptive capacity and the access to innovations developed by others – to become innovative, the firm may require changes in strategies, routines and expectations. The external factors include the existing technological paradigm, the National System of Innovation (NSI), the macroeconomic context, the degree of competition in which the firm is inserted and the regulatory framework.

In the Brazilian case, there is a growing concern over the environment. The industry has suffered increasing pressure from regulatory agencies, NGOs and the society as a whole in order to improve its environmental performance. Many companies have already incorporated environmental aspects in their management strategies, particularly those that opted for voluntary certification (such as the ISO 14000 series). The firms with global interests, i.e. the ones which are owned at least in part by foreigners, are also subject of international pressures in terms of their environmental behaviour, some of them facing the threat of green barriers in the international trade.

Nevertheless, there is a gap between the pressures and the way companies understand and act in answer to environmental issues. In order to address this question, an empirical analysis of the environmental behaviour of firms located in the state of São Paulo was carried out using data from a recent survey (PAEP/SEADE). Since the state of São Paulo concentrates most of the Brazilian industrial activity, the results obtained can be considered a good proxy for the country's industrial behaviour concerning the environment.

The paper is divided in four parts. The first one (section 2) describes the innovation theory under the evolutionary approach, highlighting the main factors that influence the capacity of firms to become innovators. Section 3 deals with the specificity of environmental innovations, emphasising the reasons why some firms decide to adopt environmental innovations and others not. Section 4 presents the results of the empirical analysis carried out using the PAEP/SEADE survey, testing the main theoretical hypothesis discussed previously. Finally, section 5 summarises the main conclusions of the paper.

2. Innovation under the evolutionary approach

The analysis of technological change and innovation must be considered in a dynamic perspective. From a certain moment, the existing technologies may no more satisfy the firm, and many problems can only be solved by innovations. However, the results of these innovations cannot be fully anticipated and, in many cases, incremental innovations are still required, showing the inevitable uncertainty of the process. This constant mutation cannot be dealt with the static approach of mainstream, neo-classical economics. The past can be analysed historically, but the present and future perspectives require an evolutionary approach.

According to evolutionary economics[2], technological knowledge can be codified or tacit. In the first case, knowledge can be transmitted by blueprints or procedure descriptions on how to employ a new technology. In contrast, tacit knowledge can only be acquired by use, since it is partially dependent on personal experiences that cannot be easily transmitted and codified. Acquiring technological knowledge is a learning process, which can be more difficult as the degree of tacitness increases (DOSI, 1988). The technologies can be classified as universal – when knowledge is widespread and associated with a broad range of applications –, or specific – in the cases when they result in particular procedures developed by experience. Other important distinction refers to public, open access technologies, and the private ones, protected by tacit knowledge or patents and other forms of keeping industrial secrets.

For the evolutionary economists, firms cannot be treated as having the same objectives because they are different and these differences are essential to their understanding. Each firm has routines, strategies and specific competences that will determine their capacity of surviving (NELSON & WINTER, 1982). This is directly related to the way it perceives and solves problems: innovations are answers to those problems faced by the firm.

The innovative process corresponds to all activities that generate technological changes and the dynamic interaction between them, not necessarily being novelties (HALL, 1994). When innovating, the firm

searches a solution for a certain problem that is solved inside a technological paradigm, i.e., inside patterns of solutions widely accepted based on the principles of natural sciences. Once established the technological paradigm, innovations become selective in the capacity of solving problems, at the same time that they undercover other solutions outside that technological paradigm. When the difficulties to find solutions inside that technological paradigm become considerable, there is a strong incentive for a paradigm change; however this is not a sufficient condition, since a new paradigm also requires advances in the basic knowledge, and other institutional and market conditions (DOSI, 1984).

In the current technological paradigm, one determined technology is selected. According to B. Arthur (quoted by LÓPEZ, 1996), the technology is not elected because it proved to be the most efficient, but turns out to be the most efficient because it was elected: the more they are used, the more attractive the technologies become. The technology is *path-dependent*, creating a *lock-in effect*, constraining the firms to the most spread technologies and to the current technological paradigm, therefore affecting their innovation capacity.

This rationale leads to the question of what forces allow the firm to generate and adopt innovations. There are a number of factors, which influence that capacity to become innovators. They can be grouped in terms of internal and external factors. Internal factors to the firm include its specific competences to solve problems, its absorptive capacity and access to innovations developed by other firms. Among the external factors there are the current technological paradigm, the National System of Innovation (NSI), the macroeconomic context, the degree of competition in which the firm is inserted and the regulatory framework.

The capacity to solve problems, the first of the internal factors, is accumulated over time. The skills and knowledge owned by the firm, acquired by experience, determine its capacity to create or absorb knowledge, depending on investments in research and development (R&D), individual knowledge of the employees, size and nature of the company (public, private, transnational, etc.), activity sector and degree of specialisation.

The second internal factor is directly related to the first one. The absorptive capacity is defined as the skills of the firm to recognise the value of new information, to assimilate and apply it to commercial uses, being crucial to its capacity to innovate (COHEN & LEVINTHAL, 1990). These skills to evaluate and use the external knowledge is a function of the level of previous knowledge, since the pre-existence of a common language and other basic patterns between the firm and the external knowledge makes easier the use of the information in a productive way. Thus, the absorptive capacity is a co-product of R&D and the tacit knowledge acquired via production. In that sense, training activities are another way to invest in the absorptive capacity and in R&D, even if no immediate results are obtained. On the other hand, this investment to increase the absorptive capacity is expensive and can be considered as a sunk-cost[3].

The access to innovations developed by others is not free and, in general, presents high costs. Innovations cannot be easily bought as an ordinary commodity, given the lack of information of the potential users, the strategy of the innovator to avoid competitors hiding the innovation, protection by patents and other forms of intellectual rights, and the costs of maintaining the firm with a high absorptive capacity. In other words, the capacity of the firm to innovate is limited by the high costs of internal R&D, or the high costs of buying the technology from others, and depends on the endogenously accumulated capacities in the technical/productive fields.

The current technological paradigm, the first of the external factors, constrains the capacity to innovate because it defines the scientific pattern in which innovations must be circumscribed. Changes in this paradigm may induce the firm to become more or less innovative, depending on its internal factors.

The NSI, the second external factor, constitutes the organisational system responsible for the development of science and technology (S&T) inside a nation. It is a complex institutional arrangement involving the R&D laboratories of the firms, the research institutes and universities, the funding agencies, the educational institutions, and the legal institutions (regulating the competence conditions, intellectual property rights, etc.)

The NSI must be considered according to its three dimensions: the learning capacity, the institutions, and the net of interactions between them. Therefore, an efficient NSI is a powerful incentive for the firms to become innovators.

The macroeconomic context is another external factor interfering in the process. Firms have great difficulty to make risky decisions under great uncertainty, paralysing the innovation process even if they are able to innovate. Symmetrically, macroeconomic stability generates confidence, encouraging the innovation decision.

The degree of competition in which the firm is inserted is crucial in the decision of creating or adopting innovations. For the evolutionary school, competition is the engine of innovation. In competitive markets, the innovation becomes the differentiation factor between the firms and the competitors, also being the only way to survive in the market. In this perspective, the firm has only two options: to innovate or to die.

Finally, the regulatory framework also affects the innovation process. Some sectors require more regulation according to the kind of activity and market structure in which they are. For instance, the economic activities with higher environmental impacts are subject to specific controls, which can turn out to be incentives to innovations, depending on the objectives and instruments of the environmental policy. This point is detailed in the next section.

3. Environmental innovations

Environmental problems must be studied in a dynamic perspective, too. Historically, the nature of these problems has changed with time - KEMP & SOETE (1990) give an example, when they refer to environmental problems caused by the use of horses as a means of transport in London a century ago[4]. Nowadays, this problem is no more relevant, because of the substitution of horses by cars for transportation. However, other environmental problems were caused because of this substitution: the emission of local and global pollutants,

traffic jams and a high number of people dying or becoming handicapped because of accidents.

The question of cumulativeness and irreversibility of environmental problems is equally relevant. In the first case, new problems appear as the degradation of the environment increases. The accumulation of sulphur dioxide in the atmosphere, for example, generates acid rain, creating the need for innovations to deal with the problem. In terms of irreversibility, innovations are necessary to avoid environmental losses that can not be recovered or can be recovered only partially, in general with high costs. For instance, to avoid the extinction of some marine species, innovations in fishing methods are necessary. Deforestation leads not only to biodiversity losses, but also to erosion and degradation of soils. Recuperation and afforestation technologies become indispensable to recover some of the natural properties of the ecosystems, in many cases requiring a considerable number of incremental innovations. These innovations may or may not bring another environmental problems, as in the case of the replacement of horses by cars.

Therefore, either because of natural mutation or anthropic interference, the environment is in constant evolution and, as in the analysis of innovation process, it can be adequately studied under an evolutionary perspective. This reinforces that the analysis of environmental innovations must be undertaken using the evolutionary economic theory, emphasising the dynamic vision of the economic processes.

The firm's capacity to create or adopt environmental innovations is decisive for improvements in local and global conditions – adequately managing natural resources, controlling pollution, etc. Environmental improvements may be translated as less use of natural resources and energy per unity of output (better efficiency in input use), less pollution and recovery of degraded ecosystems, expanding the economic possibilities inside the environmental limits. Environmental innovations are fundamental to harmonise preservation and economic growth, allowing a better access to consumption for a greater number of people.

The solutions for pollution problems can be either *end-of-pipe* (EOP) or *pollution prevention* (PP). In the first case (EOP), toxic substances are treated before their emission to the environment – contamination control – or the EOP refers to the cleaning up of degraded ecosystems. The second case (PP), also associated with the concept of *eco-efficiency*, includes the adoption cleaner technologies, improvements in the efficiency of production through innovative management, less residuals generation and recycling of byproducts (LÓPEZ, 1996). The PP approach foresees changes in adopted technologies and management practices, while the EOP approach is based in already existing technologies, which can be better considered as palliatives than definitive solutions that effectively reduce emissions and residuals (as in the case of PP). For this reason, the definition of innovations is restricted to those associated to the PP approach.

Nevertheless, the limits between EOP and PP solutions are not clear in practical terms. An EOP treatment may recover substances that can be recycled. Furthermore, an eco-efficient solution does not eliminate completely the harms to the environment, thus requiring complementary EOP treatment. In other cases, instead of being complementary, it is possible that these two kinds of treatment lead to conflicts in short and long term objectives (KEMP & SOETE, 1990). Eco-efficiency (PP) is a long term objective and requires policies that encourage the generation and adoption of environmental innovations. EOP solutions aim at emissions control in the short run and their access is easier, because they can be adapted to existing technologies without radical changes in production and organisation of the firm. Hence, environmental policies that target pollution reduction in the short run through EOP solutions may discourage the adoption of more radical changes.

There are three relevant questions in the relationship between technology and the environment (FOREY & GRÜBLER, 1996). The first one refers to the uncertainty, unfamiliarity and dispersed knowledge in the generation and distribution of technologies, including those related to the environment. New technologies are associated with uncertainties concerning their properties, and current and future impacts. These impacts may be associated to the uses of the technologies and the magnitude of their diffusion and potential cumulative impacts. The

unfamiliarity is connected to restrictions in the access to new knowledge because "*there is simply a difference between knowledge that may exist somewhere and knowledge that is available in the right form, at the right time, to the right people*" (FOREY & GRÜBLER, 1996:8). Moreover, knowledge concerning the environment is disperse, with a potential role for the new information technologies to minimise these problems.

The second question refers to the tensions between inertia and stability of existing technologies and the factors inducing to technological change, including environmental conservation. As already mentioned, technologies are the result of previously defined trajectories, creating a *lock-in* effect. The generation of eco-efficient technologies becomes a challenge, even though the potentially inductive role of environmental criteria. An important question arises: how to surpass the technological inertia to accelerate the transition towards new technologies and institutional configurations, which internalises the question of environmental conservation?

The last question deals with the policy dilemmas concerning environmental questions. The objectives of these policies in the short and long run may be not compatible, as already referred to in the issue of EOP and PP solutions. Conflicts may also arise between public policies and controls, and the innovation behaviour of the firms. Moreover, the technological diversity required for the different environmental questions is potentially incompatible with the trend for standardisation, in order to reduce costs and generate returns of scale. Finally, there is the dilemma between the need to accelerate the creation and diffusion of environmental technologies, and the necessity to minimise the technological irreversibility.

The creation and diffusion of environmental technologies differ from the traditional process of technical change, which usually consists in the succession of newer and more efficient production techniques. There are essential factors to the development and diffusion of environmental technologies in different economic sectors. These factors can be separated in terms of the supply and demand of environmental technologies (KEMP & SOETE, 1990).

Technological opportunities are a fundamental supply factor. These opportunities differ in sectoral terms, and depend on the available equipment and the existing scientific and technical knowledge - depending on them, the required solution can be easily achieved with existing technologies, or become a difficult question without answer even in the near future. Another factor affecting the supply of environmental technologies refers to the conditions of appropriability. The social interest in the fast diffusion of these technologies will justify the pressure to reduce the time of appropriability but, with the growing expectation of more rigid restrictions, the control of cleaner technologies may become an important competition factor. Finally, the instability of the demand for these technologies impedes the full development of the industrial sector dedicated to them.

Among the factors affecting the demand for environmental technologies, there are problems related to knowledge and information. These include both technical competences to adapt new technologies and knowledge over which techniques are available, how to access and how to fund them. Insecurity and uncertainty in the adoption of new technologies, given the risks involved, are other factors affecting demand. New technologies require changes in routines and training, again with uncertain results. In addition, there is the risk of the technology becoming prematurely obsolete because of changes in environmental standards, and the evaluation of these risks vary widely, among firms and sectors.

The relationship between producers/users also affects the demand for environmental technologies. Given the diversity of environmental problems, it is difficult to imagine a producer of clean technologies for all sectors. Moreover, the producer of clean technologies will rarely be the most important supplier of technologies to the companies. The last factor pointed out refers to the distinction between innovations in products and processes, which differ considerably. Product innovations must obey to the demand of consumers for what they consider as "ecologically correct" products, depending on the importance they attribute to each of the components of the environment, and their willingness to pay for this kind of product. Process innovations are related to the objectives and values of the firm, with predominance of cost-efficiency factors.

The market structure also influences the diffusion of environmental technologies. In general terms (despite of very important exceptions), small and medium companies have less perception of environmental problems and information on environmental technologies. It is expected, thus, that these firms are less inclined to be innovators. Other decisive components are the degree of competition between firms and their financial situation. Markets where competition is based on lower prices, where profit margins are low or with low degree of competition (monopolies or protected markets) tend to negatively influence the decision to adopt and develop environmental technologies.

In summary, dealing with environmental innovations using the evolutionary approach, it is possible to formulate the following hypotheses for the different behaviour presented by the firms concerning environmental innovations:

1) According to the internal factors enabling firms to generate and adopt innovations described in item 2, the innovative firms are those with higher R&D investment, higher level of qualified personnel, higher size and level of information. In the specific case of environmental innovations, one must add firms with global interests (in the case of developing countries), better financial situation, and those that include environmental concerns in their objective and values.

2) However, since factors of efficiency and costs dominate the objectives of the firm, the adoption of environmentally friendly production techniques is not a priority, despite of the growing conscience and social pressure (KEMP & SOETE, 1990). Therefore, voluntary attitudes to reduce pollution will be relatively limited, and specific controls and policies are necessary for a more widespread adoption of cleaner technologies, particularly to force big polluters to reduce their level of environmental harm.

3) Firms with high level of competitiveness are more inclined to answer positively to environmental questions, since environmental variables may become another factor to reinforce their competitive position.

4) External factors influence the decision to create and adopt environmental innovations. The incentives to innovation are positively

related to the degree of institutionalisation of environmental issues, the macroeconomic stability, the development of the NSI, and the competition in the markets where firms are inserted in.

4. Empirical evidence: the case of São Paulo

Some of the hypotheses presented in the previous section were tested using data for the state of São Paulo obtained for from the Survey of Economic Activities in the State of São Paulo (PAEP/SEADE). This survey refers to the year 1996, reaching a total number of 43,900 industrial companies, from all sectors. The answers were voluntary, explaining the difference in the number of answers in each table.

The first hypothesis to be tested was that companies with global interests (at least part of its property is owned by foreigners) tend to adopt environmental innovations and to perceive the environment as business opportunities (thus with potential losses if inadequate environmental procedures are adopted) in a higher degree than the others[5].

In the PAEP/SEADE questionnaire, the following variables were chosen to test if the firms are concerned with environmental issues:

• Business opportunities – if the answering company considered that the development of environmentally friendly products and processes is a source of increasing its business activity. Possible answers: yes/no;

• Environmental implications: market losses – if the answering company considered that its environment performance has resulted in the loss of markets, domestically or internationally. Possible answers: yes/no;

• Environmental implications: higher costs – if the answering company considered that the activities associated with its environmental performance have resulted in higher costs (investment in control measures, fines and levies, etc.). Possible answers: yes/no.

Tables 1-3 present the results from crossing the variables above with the origin of capital ownership. Table 1 shows that, from the 843 companies with global interests (capital owned at least partially by foreigners), 52.4% believe that the development of products and processes less harmful to the environment may turn out to be a business opportunity. If the companies that are solely owned by foreigners are considered, the percentage of positive answers increases to 54.9%. Among the companies exclusively owned by nationals, the percentage drops to 29.2%. Therefore, this result confirms the hypothesis that firms with global interests are more inclined to foresee the environmental questions as business opportunities than the nationally owned ones.

Table 1 – Firms that consider the environment as a business opportunity, according to their ownership – 1996

		BUSINESS OPPORTUNITY - ENVIRONMENTALLY FRIENDLY PRODUCTS AND PROCESSES		
FIRM'S CAPITAL OWNERSHIP (IN 12/31)	Data	YES *(A)*	NO *(B)*	Total *(C)*
NATIONAL	Number of firms	11,702	28,367	40,069
	Percentages A/C and B/C	*29.2*	*70.8*	
FOREIGN	Number of firms	322	264	586
	Percentages A/C and B/C	*54.9*	*45.1*	
NATIONAL AND FOREIGN	Number of firms	120	137	257
	Percentages A/C and B/C	*46.7*	*53.3*	
Total of firms		12,144	28,768	40,912
	Percentages A/C and B/C	*29.7*	*70.3*	

SOURCE: Fundação Sistema Estadual de Análise de Dados – Seade. Pesquisa da Atividade Econ. Paulista – Paep 1996.

Nevertheless, table 2 shows that only 11.4% of the companies with global interests admitted market losses because of the environmental effects of their activities. This percentage falls to only 4.3% for the nationally owned companies, and rises to 12.3% if the answers are restricted to the companies exclusively owned by foreigners. So, most of the answers (95.6%), independently of the origin of capital, pointed out that they did not perceive any losses in either domestic or international markets as a consequence of their actions to the environment.

Table 2 - Firms that consider market losses caused by the environmental consequences of their actions, according to their ownership - 1996

		ENVIROMENTAL CONSEQUENCES - MARKET LOSSES		
FIRM'S CAPITAL OWNERSHIP (IN 12/31)	Data	YES *(A)*	NO *(B)*	Total *(C)*
NATIONAL	Number of firms	1,721	38,326	40,047
	Percentages A/C and B/C	*4.3*	*95.7*	
FOREIGN	Number of firms	72	511	583
	Percentages A/C and B/C	*12.3*	*87.7*	
NATIONAL AND FOREIGN	Number of firms	24	234	258
	Percentages A/C and B/C	*9.3*	*90.7*	
Total of firms		1,817	39,072	40,889
	Percentages A/C and B/C	*4.4*	*95.6*	

SOURCE: Fundação Sistema Estadual de Análise de Dados – Seade. Pesquisa da Atividade Econ. Paulista – Paep 1996.

Table 3 shows that 41.1% of the companies with global interests considered that their costs were increased because of the environmental consequences of their activities. This percentage is reduced to 14.8% for the nationally owned companies. In total, 84.7% considered that there were no cost increases because of environmental questions.

Table 3 - Firms that consider rising costs caused by the environmental consequences of their actions, according to their ownership - 1996

		ENVIROMENTAL CONSEQUENCES - RISING COSTS		
FIRM'S CAPITAL OWNERSHIP (IN 12/31)	Data	YES *(A)*	NO *(B)*	Total *(C)*
NATIONAL	Number of firms	5,919	34,131	40,050
	Percentages A/C and B/C	*14.8*	*85.2*	
FOREIGN	Number of firms	242	341	583
	Percentages A/C and B/C	*41.5*	*58.5*	
NATIONAL AND FOREIGN	Number of firms	104	155	259
	Percentages A/C and B/C	*40.2*	*59.2*	
Total of firms		6,265	34,627	40,892
	Percentages A/C and B/C	*15.3*	*84.7*	

SOURCE: Fundação Sistema Estadual de Análise de Dados – Seade. Pesquisa da Atividade Econ. Paulista – Paep 1996.

Concluding, nationally owned companies do not perceive the environmental issues in the same way as the companies with global interests, confirming the hypothesis presented in section 3. However, most of the companies did not consider market losses because of environmental protection measures, thus refusing another of the hypotheses previously discussed. Note that a better definition of companies with global interests would have to consider too the domestically owned companies which exports a considerable share of its production; it is possible that with this new classification the differences between the two groups of companies would become even greater.

The variables present in the survey chosen to reflect the adoption of environmental innovations were:

• Factors motivating the company to innovate (from 1994 to 1996): environmental preservation - indicates the degree of importance given by the answering company to the strategy of environmental preservation as a motivation factor to innovate. Possible answers: indifferent, less important, important, very important, or crucial.

• Investment: changes in the production process for environmental reasons (from 1994 to 1996). Possible answers: yes or no.

Table 4 shows the crossing of the first variable with the origin of capital. The vast majority (85.5%) of the firms with global interests considers the strategy of environmental preservation as important, very important or crucial as a motivation factor for the company to innovate. This percentage falls to 78.4% for domestically owned companies. This shows that most of the companies are more inclined to innovate because of environmental questions, and that this behaviour is more evident in the companies with global interests.

Table 4 – Degree of importance of the environment protection strategy as a factor which motivated the firm to innovate, according to their ownership – 1996

		FIRM'S CAPITAL OWNERSHIP (IN 12/31)			
FACTORS WHICH MOTIVATED THE FIRM TO INNOVATE – ENVIRONMENT PROTECTION (94-96)	Data	NATIONAL	FOREIGN	NATIONAL AND FOREIGN	Total
INDIFFERENT *(A)*	Number of firms	1,095	10	16	1,121
	Percentages A/F	*14.7*	*3.3*	*14.8*	
LESS IMPORTANT *(B)*	Number of firms	518	22	12	552
	Percentages B/F	*6.9*	*7.2*	*11.1*	
IMPORTANT *(C)*	Number of firms	2,361	113	22	2,496
	Percentages C/F	*31.6*	*36.8*	*20.4*	
VERY IMPORTANT *(D)*	Number of firms	2,458	109	41	2,608
	Percentages D/F	*33.0*	*35.5*	*38.0*	
CRUCIAL *(E)*	Number of firms	1,028	53	17	1,098
	Percentages E/F	*13.8*	*17.3*	*15.7*	
Total of firms *(F)*		7,460	307	108	7,875

SOURCE: Fundação Sistema Estadual de Análise de Dados – Seade. Pesquisa da Atividade Econ. Paulista – Paep 1996

Table 5 presents the companies which invested or not in changes in the production process aiming at the reduction of environmental problems. Again, the companies with global interests showed a different behaviour, with 40,8% answering positively, against only 18,3% of the domestically owned companies. Therefore, it can be concluded that companies with global interests tend to be more prone to adopt environmental innovations than the domestically owned ones, even though must of the latter also consider the environment as an inducing factor to innovation.

Table 5 – Firms that made investments in changes in their production processes for environmental reasons, according to their ownership – 1996

	FIRM'S CAPITAL OWNERSHIP (IN 12/31)			
INVESTMENT – CHANGES IN PRODUCTION PROCESSES	NATIONAL	FOREIGN	NATIONAL AND FOREIGN	Total
YES *(A)*	7,294	251	92	7,636
Percentages A/C and B/C	*18.3*	*43.1*	*35.5*	*18.7*
NO *(B)*	32,674	331	167	33,173
Percentages A/B and B/C	*81.7*	*56.9*	*64.5*	*81.3*
Total of firms *(C)*	39,968	582	259	40,809

SOURCE: Fundação Sistema Estadual de Análise de Dados – Seade. Pesquisa da Atividade Econ. Paulista – Paep 1996

Another hypothesis discussed in section 3 was that innovative firms are the ones with highest investment in R&D. In other words, companies spending more resources in R&D are more inclined to adopt innovations, including the environmental ones. The variable chosen to reflect R&D efforts was "Internal sources for innovation activities, 1994 to 1996 – R&D department", indicating the degree of importance of the internal department of R&D as a induction source of innovation development inside the company. The possible answers were indifferent, less important, important, very important, or crucial.

Table 6 shows the proportion of companies that invested in changes in the production process aiming at the reduction of environmental problems, according to the importance attributed to their internal R&D department for the innovative behaviour of the company. The higher the importance of the R&D department, the greater was the proportion of companies that invested in changes in the production process to solve environmental problems. Thus, only 28% of the companies that declared indifference to internal R&D department invested in changes in the production process. This proportion rises to 49% for the companies that declared that their own R&D departments were crucial for the innovation process inside the firm.

Table 6 - Firms that invested in changes in their production processes for environmental reasons, according to the degree of importance of their own R&D department - 1996

		INTERNAL SOURCES OF INNOVATIVE ACTIVITIES - R&D DEPARTMENT (91-96)					
INVESTMENT - CHANGES IN THE PRODUCTION PROCESSES	Data	INDIFFERENT	LESS IMPORTANT	IMPORTANT	VERY IMPORTANT	CRUCIAL	Total
YES *(A)*	Number of firms	242	193	1,277	789	380	2,880
	Percentages A/C	*27.8*	*38.3*	*39.6*	*42.6*	*49.0*	*39.9*
NO *(B)*	Number of firms	629	311	1,945	1,063	395	4,343
	Percentages B/C	*72.2*	*61.7*	*60.4*	*57.4*	*51.0*	*60.1*
Total of firms *(C)*		871	504	3,221	1,852	775	7,223

SOURCE: Fundação Sistema Estadual de Análise de Dados - Seade. Pesquisa da Atividade Econ. Paulista - Paep 1996

Table 7 shows the crossing of the degree of relevance attributed to preservation as a motivation factor for innovation, and the degree of importance of the internal R&D department. The results point out that

there is an increase in the proportion of companies that consider relevant to invest in internal R&D activities according to the importance attributed to the environment as a motivation factor for innovations.

Table 7 - Degree of importance of the environment protection strategy as a factor which motivated the firm's innovation according to the degree of importance of their own R&D department - 1996

	INTERNAL SOURCES OF INNOVATIVE ACTIVITIES - R&D DEPARTMENT (91-96)					
FACTORS WICH MOTIVATE INNOVATION - ENVIROMENTAL PROTECTION (91-96)	INDIFFERENT	LESS IMPORTANT	IMPORTANT	VERY IMPORTANT	CRUCIAL	Total
INDIFFERENT *(A)*	182	46	296	151	132	808
Percentages A/F	*25.2*	*10.4*	*10.8*	*9.8*	*21.0*	*13.3*
LESS IMPORTANT *(B)*	49	56	164	111	65	447
Percentages B/F	*6.8*	*12.7*	*6.0*	*7.2*	*10.4*	*7.4*
IMPORTANT *(C)*	221	157	933	337	137	1,784
Percentages C/F	*30.6*	*35.6*	*34.1*	*21.9*	*21.8*	*29.4*
VERY IMPORTANT *(D)*	201	153	914	599	195	2,062
Percentages D/F	*27.8*	*34.7*	*33.4*	*38.9*	*31.0*	*34.0*
CRUCIAL *(E)*	69	29	429	341	99	967
Percentages E/F	*9.6*	*6.6*	*15.7*	*22.2*	*15.8*	*15.9*
Total of firms *(F)*	722	441	2,737	1,539	628	6,067

SOURCE: Fundação Sistema Estadual de Análise de Dados - Seade. Pesquisa da Atividade Econ. Paulista - Paep 1996

The results above confirm that companies investing internally in R&D are more able to generate or adopt innovations, including the ones destined to environmental issues. Companies which attributed a higher degree of importance to their R&D departments are the ones with higher positive answers in terms of innovation in processes (carried out to reduce environmental damage), and perception of environmental restrictions as a motivation factor in the innovation process.

5. Conclusion

A common criticism to ecological economics is the absence of well-structured models that can replace the standard mainstream analysis in both theoretical and policy making grounds. The main objective of this paper was to show that evolutionary economics is a valid alternative approach to neo-classical microeconomics which is compatible with the proposals of ecological economics, particularly the uncertainty and irreversibility principles. In that sense, the incorporation of environmental issues in evolutionary economic models can be considered a valid form to expand the ecological economics research agenda, and a useful tool to theoretically support policies oriented towards sustainable development.

The theoretical review carried out in the first part of this paper presented a set of hypotheses determining the interaction between competitiveness and environmental performance according to factors inside and outside the firm. Some of these hypotheses were empirically analysed, using data from an industrial survey in the state of São Paulo. It was shown that companies with global interests are the most inclined to foresee business opportunities from environmental requirements, as predicted in the available literature[6]. However, a related and also widespread hypothesis - that firms may lose markets if they do not behave properly in environmental terms - was not considered by most of the answering companies, independently of the origin of the controlling capital. Almost half of the companies with global interests observed increasing costs caused by environmentally related activities, but the vast majority of the domestically owned companies did not perceive additional costs for the same reasons (showing, again, a different pattern of behaviour between these two groups).

The survey confirmed the hypothesis that firms with global interests are the most prone to adopt environmental innovations, even though most of the nationally owned companies also consider environmental issues as a motivation factor to innovate. Another hypothesis confirmed was that companies with highest efforts in R&D are the most likely to adopt environmental innovations. The proportion

of companies that consider important internal R&D activities increases if only the companies that invested in environmental protection are considered. Moreover, the consideration of environmentally friendly technologies as incentives to innovation is more clearly present in companies that attribute more importance to their internal R&D departments.

A number of other hypotheses could not be empirically analysed because of the lack of suitable variables in the survey to test them. Nevertheless, in the analysis of the Brazilian industrial firm, one must have on mind that the capacity to find solutions for specific problems is *path-dependent* and the firm is connected to a certain technology, with the possibility of generating a *lock-in* effect, impeding the adoption of environmental technologies. Note also that external factors are also important to explain the reduced level of diffusion of environmental innovations in Brazil: the macroeconomic uncertainty, associated with very high inflation until 1994, and the vulnerability to speculative capital outflows after that; and the absence of an efficient and integrated NSI.

One important limitation of this study is that domestically owned companies with important export activities were not included in the group of companies considered as with global interests. This and other problems may be solved with new studies, especially if other databases are used, allowing the comparison of results. Only a few number of hypotheses were tested, and a lot of questions still require answer. Two are particularly important: (i) how to encourage the generation and diffusion of technological knowledge, to flexibilize regilations, and to increase the knowledge and learning capacity about the environmental impacts of technologies? (ii) how to overcome the technological inertia to accelerate the transition towards new technologies and institutional configurations that internalise environmental questions?

It is always important to remember that the direction of technological development must be directed towards sustainable development, in a way that the expansion of the limits of economic growth is compatible with the reduction of social disparities and ecological equilibrium. The full incorporation of environmental issues in the technological paradigms is a necessary condition (but not sufficient) for the simultaneous achievement of these goals.

Notes

[1] The most important contribution following this approach was the report for the Club of Rome (MEADOWS *et alli*, 1996).

[2] Giovanni Dosi, Christopher Freeman, Richard Nelson and Sidney Winter are, probably, the most known representatives of this school, which is heavily influenced by the work of Joseph Schumpeter.

[3] Sunk-costs cannot be recovered if the firm leaves the market. In general, they represent specific assets of the firm.

[4] Since one horse produces around 16 kg of manure daily, the high concentration of these animals forced the city to employ about 6,000 crossing sweepers to clear the way for pedestrians (KEMP & SOETE, 1990).

[5] In the PAEP/SEADE survey, companies with global interests were considered as the ones with capital ownership classified as *foreign* (100% of the capital is owned by foreigners) and *national and foreign* (at least one of the controllers is a foreigner).

[6] As previously stated, this survey can be considered representative for the whole country since São Paulo concentrates half of the total Brazilian industrial activities.

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