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Environmental Performance of the Assembly Plants Industry in the North of Mexico

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The northern border of Mexico, a region with great tradition and rooting of the assembly plants industry, outstands by its specialization in the processing of electronic products and automobile parts. Also, this industry outstands by restructuring its techno-productive capabilities derived from its integration with North America, which has aroused the interest about the resulting environmental problems. As depository of direct foreign investment, this region demands to design efficient mechanisms for an environmental management actively involving all the local actors. The deepness of liberalization of the Mexican economy has not been a condition for Mexico to specialize itself in "dirty" industries because since the North America Free Trade Agreement has taken effect, it is favoring less polluting industries as this is compliant of the environmental regulations, which are determined by the cooperation among companies and government through inspection and promotion of voluntary self-management programs and through the environmental policy imposed by the corporation to its affiliates by means of quality and environmental international certifications (ISO 9001, 9002, 14001, and 14002). The objective of this work is to analyze the environmental performance of foreign companies operating under the assembly plants industry regime, considering the relationship between industrial upgrading and environmental performance.

KEY WORDS: environment, environmental learning, industrial upgrading, techno-productive complexity, environmental cooperation, NAFTA, Mexico

Foreword

The North America Free Trade Agreement (NAFTA) among Mexico, United States, and Canada increased the interest to know the impact of the growing exportation assembly plants industry (EAI) on the development of countries, such as Mexico, in the relevance of transnational companies in the international context and, particularly, in the predictions that in the context of the NAFTA, a bigger direct investment of highly industrialized countries was coming to Mexico to take advantage of the virtual disappearance of tariffs and the low cost of labor force.

In Mexico, the increasing importance of the EAI is reflected in the fact that in four decades, the assembly plants program became a program that has served as base for regional industrial development on the northern border. Moreover, since the 1980s and until the end of the 1990s, the EAI had an outstanding growth degree, becoming

the most important exporting industrialization model of Mexico and, at least until mid-2001, one of few dynamic cores of nontraditional exportations and highly competitive worldwide (Mortimore, 2000).

The maquiladora industry is part of the international economy, as a result of this, there has been a press for international companies to improve their environmental management systems as competence requirement (Constantino, 1996; Porter and Van Der Linde, 1995). After NAFTA was signed, the Mexican government had the need to strengthen the institutional framework for environment protection, restructuring and creating the institutions on the matter (Ministry of Environment and Natural Resources [Semarnat] and Federal Ministry of Environmental Protection [Profepa]) and the judicial instruments of normative observance (General Law of Ecological Balance of Environmental Protection [LGEEPA]). This entire institutional environment partially weakened the argument that liberalization would create a "paradise" in the country for the more polluting companies (Gallagher, 2000; Jenkins, 2003, p. 97; Schatan, 2000). Even if the idea persists that there was little advancement in the design and the taking of policy mechanisms to mitigate the environmental impact of the trade increase (Nauman, 2001, p. 2).

On account of an evolutionary process in which the EAI has been immersed, learning capabilities arise for the environmental framework. As a result, the industry under study has introduced clean environmental technologies, has created departments and/or positions to manage cutting-edge environmental technologies, to incorporate certification processes and to improve personnel training in handling toxic substances, and also has implemented protocols for pollutant disposal, among other aspects.

The objective of this work is to analyze the environmental performances of foreign companies operating under the assembly plants industry regime. In order to achieve this, we develop *techno-productive complexity levels* and principal components methodology to analyze the current differences in their environmental performance, which will refer to the existing relations between industrial upgrading[1] and environmental performance.[2] We also use an environmental performance index (EPI) in order to identify those variables which are more sensible to environmental performance.

Our hypothesis suggests that the necessity to implement environmental protection measures is associated with the level of the manufacturing evolution of assembly plants. It is expected that higher levels of techno-productive complexity implies greater possibilities for the plants to reduce the negative environmental impacts in the border region where the EIA is located.

We have organized the article as follows: in the first section, there is a discussion about the company as a place of learning and about the construction of productive and environmental competences; in the second section, there is the methodology which supports the empirical analysis of the techno-productive levels and their environmental performance; in the third section, there are exposed the results of the empirical analysis of the survey in relation to the EIA and its environmental performance, and a brief description of the institutional framework for environmental protection in Mexico since the signing of the NAFTA, as well as the EPI; and in the fourth and last section, the conclusions and recommendations are exposed.

1. The Company as a Place of Learning and Social Construction of Productive and Environmental Competences

There are several studies (Carrillo, García Jiménez, & Gomis, 2004; García Jiménez, 1999, 2002; Méndez, 1995; Mercado, 2001; Montalvo, 2002, 2004) regarding the relation between technological and organizational capabilities of assembly plants and their environment. Generally, these researches support the idea that environmental performance of the EIA has been positively impacted by the implementation of quality certifications of ISO 9000 type and, particularly, those of ISO 14001 type, in addition to the productive and technological transformations that have made possible an improvement of the plant's organization, and human resources allocated to the environmental protection (Buitelaar, Padilla, & Urrutia, 1999; Carrillo, Mortimore, & Alonso, 1999; García Jiménez, 1999; González & Barajas, 2004). However, the specific connection between the productive evolution and the environmental performance is an analytical line that is constantly in construction because of the diversity of conceptual parameters that are used to characterize the technological and organizational change of the assembly plants (Alonso & Carrillo, 1996; Barajas & Rodríguez, 1989, 1990; Barajas, Rodríguez, & Almaraz, 2004; Brown & Domínguez, 1989; Carrillo & Hualde, 1997; Gerber, 1999; González & Barajas, 2004) as guidelines to measure their environmental performance (García Jiménez, 1999; Kopinak & Guzmán, 2005; Lara Valencia, 2004; Mercado, 2001; Montalvo, 2002, 2004; Rojas, 1996; Schatan & Castilleja, 2005; Schatan, 2000; Stromberg, 2005).

According to Wisner and Epstein (2005, p. 5), in the review of literature known as "resource-based view of the firm" (RBV), the companies get a strategic advantage through the development of resources generating value, which are scarce and difficult to imitate. Moreover, environmental protection resources are among these resources.[3] The same author adds that a proactive environmental strategy needs to be coordinated through what is called functional capacities and these should be immersed in the culture of the organization.

Despite the entry in force of the NAFTA, the assembly plants currently find themselves in the most serious predicament in their history because even if they are more and more competitive as plants, as a sector they lose competitiveness (Carrillo & Gomis, 2003). However, we have to admit that agreements such as the NAFTA exerted pressure on the Mexican government to strengthen the implementation and follow-up of environmental regulations (Wisner & Epstein, 2005, p. 6). Furthermore, because of its heterogeneity in their competitive scales, not all the companies are equally ready to face the new challenges of globalization (Barajas et al., 2004; Gerber & Carrillo, 2002, 2003), even beyond the so dissimilar regional trajectories that have followed the border assembly plants of the north and south (De la O & Quintero, 2002).

Traditionally, the study of the environmental behavior[4] of assembly plant companies has its origin on the concern to understand the process through which the agents take new attitudes in the face of environment (Brown, 1998; Domínguez, 1998, 2005; Montalvo, 2004). The nature of economic incentives needed for companies to assume a productive behavior in favor of the environmental protection has been

explored (Rojas, 1996; Mercado, 1999). The explanation in these researches about behavior of economic agents is based on the assumption that those who have perfect information regarding the set of environmental options they have available, whose rational orientation allows them the option of maximizing their marginal utility.

In these works, the assumptions of "unlimited rationality" and "perfect information" are parameters of orientation on decisions of economic agents explaining environmental behavior, which characterizes agents' perception as unhistorical and homogeneous. It is regarding the possibilities of these actors to apply rational choice and equal terms to access environmental options offered in the market. This vision leaves out the role of institutions (i.e., governmental and corporative) on the reorientation of environmental behavior of economic agents (Casalet, 2002). In turn, it does not consider the learning processes with which the best options for improving its environmental performance are chosen. As a result, the environmental behavior of a company is analyzed as an abstract and remote dimension to interactions with its environment.

As for Montalvo (2004, p. 74), some of the effects of strategic technological trajectories are related to the costs and the performance of products and processes and their integration to a socioeconomic context, which includes cumulative knowledge and abilities, productive capacities, infrastructure, regulations, social rules, and lifestyle of people.

In contrast, an additional focus to observe the environmental behavior of companies consists of considering a firm as an economic agent with imperfect information regarding the set of possible environmental options, acting with rationalities quoted to its operation setting, and where its marginal utility is not necessarily maximized. With this focus, the construction of environmental routines and capacities to the interior of assembly plants is a product of techno-productive learning process and of its internal social organization in a defined institutional context (Dosi & Malerba, 1996; García Jiménez, 1999; Magnusson & Ottoson, 1997; Nelson & Winter, 1982).

Within this perspective of rationality, we can place what was exposed by Wisner & Epstein (2005, p. 7) in the sense that companies tend to invest in environmental capacities because environmental regulations are seen as a supplementary effect of the industrial performance. Moreover, as Kopinak (2002, p. 15) affirms, as the industrial plant includes greater number of operations in its production, also the danger of a greater disposal of hazardous residuals[5] increase, therefore, a more aggressive environmental policy is required.

On account of these circumstances, our hypothesis implies that there is a need to observe the environmental behavior as a product of technological and productive learning processes that, in the case of assembly plants, are a result of the overlapping of local and global conditions converging into its operational function. As seen in Figure 1, at the local level, we have influence exerted by the application and compliment of environmental regulations, while at the global level, there are productive and environmental trends transferred to assembly plants through their corporative network.[6] In this sense, environmental behavior is not only a product of different phases of productive upgrading (with learning processes and creation of specific

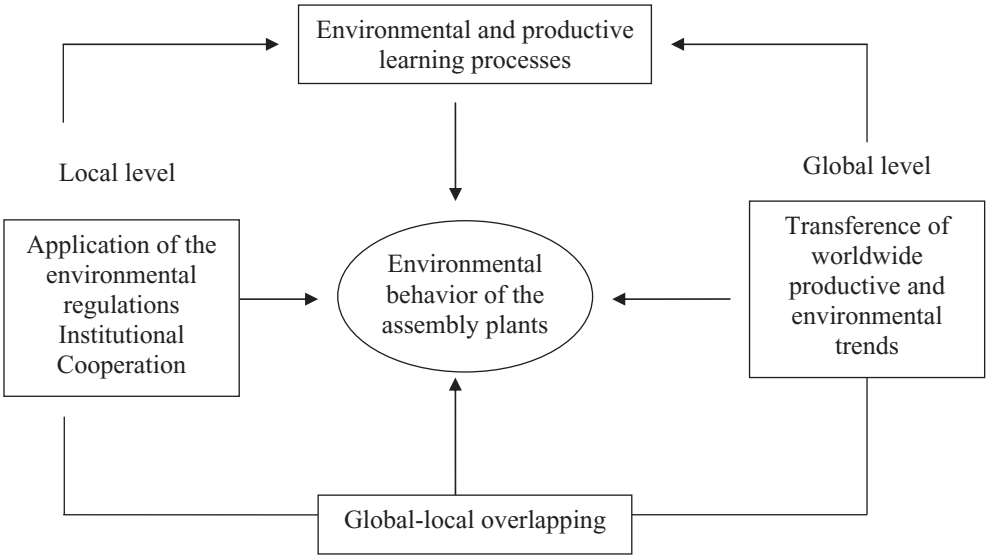

Figure 1. Conditioning Elements of the Environmental Behavior of Assembly Plants.
Source: Own elaboration.

environmental competences), but also is the way how environmental behavior impact them.

Thus, the "limited rationality" and the "imperfect information," as theoretical principles, allow us to come closer to the relationships between the productive and the environmental competences, not as a static and monolithic connection, but as a dynamic interaction that corresponds to the different levels of industrial evolution.

Based on what was exposed above, the analysis of environmental performance regarding industrial upgrading[7] has, as baseline, the following assumptions: Any activity having as objective the environmental protection has economic expenses in addition to normal expenses of a company, and economic actors (in this case, the plant, the production and the environment managers) take decisions based on limited rationality, according to which, the productive learning, the nature of its relationship with its corporative network, and the regulations are elements guiding the environmental behavior of the plants.

2. Methodology

To compare our hypotheses, we used a survey of the research project *"Technological Learning and Industrial Upgrading: Perspectives for the Formation of Abilities of Innovation in the Assemblies Plants of Mexico"*[8] that the El Colegio de la Frontera Norte (The Colef) completed in the year 2002 to 298 managers of assembly plant companies, in three border cities of the north of Mexico: Tijuana, Mexicali, and Ciudad Juárez, and in the electronic and auto parts sectors and among their suppliers. The results of this survey allowed us to evaluate the techno-productive and organizational profile

Basic techno-productive complexity (BT-PC) (Indicators)
1.- Assembly of parts, components or subassemblies
2.- Assembly of final products
3.- Packaging
Intermediate basic techno-productive complexity (IBT-PC) (Indicators)
1.- Manufacturing of components
2.- Automatic insertion of components
3.- Plastic Injection
4.- Product Testing
Intermediate advanced techno-productive complexity (IAT-PC) (Indicators)
1.- Manufacturing of final products
2.- Tools manufacturing
3.- Machinery and equipment manufacturing
4.- Machining
Advanced techno-productive complexity (AT-PC) (Indicators)
1.- Product design
2.- Research and development (R&D)
3.- Elaboration of blueprints

Figure 2. Techno-Productive Complexity Levels.
Source: Own production based on several authors and in the Colef Survey, 2002.

of the EIA, as well as its participation in the learning and industrial upgrading processes. Included in this profile are: (i) the incorporation of environmental issues to specific activities of the organizational structure (departments); (ii) the investment on environmental technologies; (iii) the way those are acquired; (iv) the innovation processes in the area; (v) the participation on certification processes such as the ISO 14001 and 14002; and (vi) the measures for environmental protection.

The procedure to check our hypotheses included the determination of the techno-productive evolution based on the methodology of abilities complexity (Bell & Pavitt, 1992, p. 4; 1995) with which we determined: (i) the groups of complexity in which we classified the companies in accordance with their learning and innovation abilities into four levels: basic, intermediate basic, intermediate advanced, and advanced; (ii) analysis of environmental behavior by type, considering only two of the main techno-productive levels of complexity: basic and intermediate advanced; and (iii) construction and analysis of the environmental performance index (EPI).

In Figure 2, there is the group of indicators used to create the different levels of techno-productive complexity. A regression analysis was used to obtain the differentiated weight resulted among the four groups described in the diagram, which constitute the four levels of tecno-productive complexity. The procedure followed was through the application of a statistical processing consists of the dichotomial recoding of the variables selected of the survey applied in order to homogenize them and obtain their statistical values by means of the regression analysis through the SPSS software.

$$\text{Theoretical value} = w_1X_1 + w_2X_2 + w_3X_3 + \ldots + w_n X_n$$

Where X_n is the observed variable and W_n is the determined pondering for multivariate technique. The variables we use to build an equation are the folllowing:

Basic techno-productive complexity (BT-PC) = X_1
Intermediate basic techno-productive complexity (IBT-PC) = X_2
Intermediate advanced techno-productive complexity (IAT-PC) = X_3
Advanced techno-productive complexity (AT-PC) = X_4

Also, we used a principal components method to analyze which are the main environmental problems that the assembly plants are confronted with. For other dimensions of our examination, this technique cannot be used.

The EPI was created based on the variables related with human and financial resources that the plants allocate for the environmental protection.

3. Research Findings: Productive Evolution and Environmental Behavior

In this section we present, first, a brief discussion about institutional framework for the environmental protection in Mexico. Second, the main results of the research characterizing the environmental performance of the assembly plants.

3.1. The Institutional Framework of Environmental Protection in Mexico[9]

Once the NAFTA was signed, the idea that Mexico would become a "paradise" for the polluting companies of the United States and Canada was extended. The existence of more relaxed regulations compared to those of our trade partners motived that Mexican government had begun with a restructuring process of institutional framework devoted to environmental protection. The creation of the Semarnat and the Federal Ministry of Environmental Protection (Profepa), along with the amendments to the LGEEPA, were part of this institutional strengthening required to soften the critics of environmental groups of the United States and Mexico.[10] In the free trade scope, the efforts resulted in the signing of the Parallel Agreements for Environment and the creation of environment-oriented trinational institutions (Comission for Environmental Cooperation [CEC], North American Development Bank [NADBANK], Border Environment Cooperation Commission [BECC], etc.).

Even with these efforts, the institutional circumstances characterizing the application and achievement[11] of the regulations are: (i) lack of economic incentives to control and prevent pollution; (ii) lack of financial human resources to monitor and follow up environmental inspection works, both in companies and government; (iii) deficient structure of sanctions of environmental regulations combined with excessive bureaucratic paperwork for its complying; and (iv) scarce technical infrastructure for complying with some regulations.

Since mid-1990s, to the measures of command and control as instruments of environmental policy there has been added the promotion of environmental self-management programs (Clean Industry Program), promoted by the Profepa for the

Table 1. Techno-Productive Complexity Levels

Levels	Number of Cases	%
Basic	151	54.7
Intermediate advanced	125	45.3
Total	276	100.0

Source: Own production based on the Survey Technological Learning and Industrial Upgrading in Assembly Plants, El Colegio de la Frontera Norte (2002). Conacyt Project num. 35947-s, "Technological Learning and Industrial Upgrading. Perspectives for the Formation of Innovation Abilities in the Assembly Plants of Mexico."

companies to certify their environmental management systems, reduce number of inspections, and diminish sanctions for noncompliance during the certification phase of the program.

Despite the efforts to strengthen the institutional framework, generally, companies have a reactive environmental behavior; prevailing the strategy of correcting externalities instead of avoiding them. In operational terms, that means the use of environmental technologies for control, under the economic logic that it is cheaper to use adequate productive process than pay fines for failure to fulfill regulations than to introduce changes in the production system.[12]

Using the results of the regression analysis for the techno-productive level of the companies as main variable and as a result of an iterative process of each of the productive activities (Table 1), almost 55 percent of these assembly plants exclusively perform activities classified as basic, while a little over 45 percent of them can be classified as assembly plants of intermediate advanced complexity level.

This means that a little over half of these companies continue to use the simple assembly, their routine activities have low degree of difficulty and the low salaries in these plants are their main competitive advantage.[13] Additionally, we found that an important percentage of the total number of companies in the sample, 45 percent, corresponds to an intermediate advanced complexity level because, in addition to performing the activities considered as basic, they also perform at least other activities of intermediate basic complexity level. These companies have evolved from basic levels to intermediate advanced levels of complexity, therefore, their competitive advantage is not only the low salaries and the use of poor qualified workers, but also because they perform more complex activities, such as manufacturing of final product, manufacturing of tools, manufacturing of machinery and equipment, and machining.

3.2 Environmental Situation of the Plants by Techno-Productive Level

In the following section, we analyze some of the most important characteristics of the assembly plants regarding environmental issues. First, we identify the main problems that confront the assembly plants; second, we examine the level of investment that these plants have to solve their environmental problems; and third, we discuss what is the level of participation of the assembly plants in the certification

Table 2. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.545	42.41	42.410	2.545	42.41	42.41	1.835	30.583	30.583
2	1.07	17.827	60.237	1.07	17.827	60.237	1.779	29.654	60.237
3	0.736	12.268	72.505						
4	0.614	10.231	82.736						
5	0.580	9.67	92.406						
6	0.456	7.594	100.00						

Extraction method: Principal component analysis.
Source: Idem. Table 1.

processes such as ISO 14000. Finally, we discuss the companies' main motivations to invest and take actions in order to protect the environment and we analyze how different actors participate in those actions. This analysis is crossed by the techno-productive levels of complexity in order to determine if there are some differences between the environmental behavior of assembly plants that are, on one hand, basic, and the intermediate advanced on the other hand.

Main Environmental Problems. In the survey, we consider different types of environmental problems faced by the assembly plants. Some of the most important were the following: The confinement of hazardous residuals and their reexportation, the confinement of industrial waste, access to drinking water, garbage collection and provision of sanitary services. In order to determine the most representative variables for the companies in the survey, we used a "Principal Component Analysis," and found that two are the main problems for these plants: problems to reexport hazardous residuals and to confine industrial waste. Based on the initial Eigenvalues which resulted from the principal components analysis, we found that one component explain 42 percent of the variance, and by adding a second component, it has explained 60 percent of the variance (see Tables 2 and 3, and Figure 3).[14] This is interesting because at some point, the resolution of these problems are related to local industrial infrastructure and federal regulation.

For the reason that this is an industry very sensitive to critics about its impact on the environmental development of the cities where it is located, the companies identify themselves very little with the other type of problems cited above. Moreover, because most of the plants are physically located in industrial parks, then such problems turn out to be more manageable. That is the case of the garbage collection or access to drinking water, which in both cases, are services regularly offered by the city government.

It is interesting that companies both at basic and intermediate advanced techno-productive levels are those mainly presenting the problems mentioned above: confinement of hazardous residuals and problems for their reexportation. Regarding the confinement of industrial waste, local governments of cities such as Tijuana,

Table 3. Component Matrix[a]

	Component	
	1	2
Confinement of toxic substances	0.718	–0.192
Re-exportation of toxic substances	0.597	–0.511
Confinement of industrial waste	0.644	–0.474
Access to drinking water	0.661	0.422
Sanitary services	0.760	0.259
Garbage collection	0.494	0.550

Extraction method: Principal component analysis.
Source: Idem. Table 1.
[a]Two components extracted.

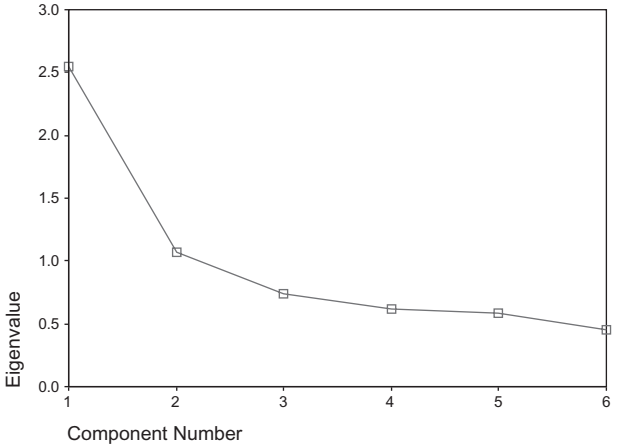

Figure 3. Scree Plot.

Mexicali, and Ciudad Juárez are confronted with serious problems because of the lack of adequate infrastructure to solve these type of problems, particularly because they do not have financial resources to create facilities for the confinement and treatment of hazardous residuals in the border cities that demand this service.

By using official information (Semarnat, 2002), there is an estimation that in Mexico there is produced about 37 millions of tonnes of hazardous residuals. This amount is similar to the amount reported by industrialized countries such as Switzerland, Germany, France, and others. From this source of information are mentioned several alternatives of solution to reduce hazardous materials, such as introduction and change of production technologies, recycling process before treatment and final disposition, and reinforcement of previous treatment of residuals to reduce the volume and the danger.

Some of the industrial activities that might produce supplementary hazardous residuals are the following: finishing of metals, assembly and production of electronic components, production of plastics and synthetic resins, oil, petrochemistry, among others (Semarnat, 2002).

Table 4. Conditions of the Environmental Expenses of the Companies by Techno-Productive Complexity Level

Condition	Basic %	Intermediate Advanced %
No expenses in the field of environment	6.0	5.6
The field of environmental expenses increased	57.0	56.0
The field of environmental expenses decreased	3.3	7.2
No change on the field of environmental expenses	33.8	30.4
Total	100.0	100.0

Source: Idem. Table 1.

In 2000, the Red Mexicana de Acción Frente al Libre Comercio and the Texas Center for Policy Studies (2000) carried out a project in which they argue that as a consequence of the growth of industrial production in the northern border of Mexico, particularly in the cities of Tijuana and Ciudad Juárez, there occurred an increasing production of hazardous residuals, which seriously impact workers, land, water, forest, and general population. The findings of this study are similar to our results. Moreover, the type of environmental problems that they detect in the northern border of México are the following: (i) illegal deposit of hazardous residuals in the limits of these cities and often in particular habitats of desertic ecosystems; (ii) direct exposition of local communities and neighborhoods to abandoned confinements of hazardous residual without being treated; (iii) deficient infrastructure of local sanitary facilities to store hazardous residuals; (iv) spills and accidents in the transportation of residuals caused by illegal transporters that lack adequate equipment, training, permits, and necessary insurance; (v) direct exposure of workers of the maquiladora industry to hazardous residuals, with awful consequences for their health; (vi) water pollution as a result of inadequate treatment by the industries; (vii) lack of interest and opposition from local, state, and federal governments to accept participation of environmental Nongovernment Organizations (NGOs) and communities in the design of public policies to manage hazardous residuals[15]; and (viii) inefficiency of emergency services in border communities to attend to industrial accidents because of deficient personnel training, insufficient equipment, tardiness in the attention of emergencies, and sometimes, refusal of the community to participate in these services.

Expenses in Environmental Protection and Effect of the Actions Taken. Other approach is to investigate if in the three years previous to the application of the survey, the companies had changed their expenses on environmental matter. The information available indicates also that in both the most important techno-productive levels of assembly plants, such expenses have been increased and that there are a few companies that do not make any investment in this field (Table 4).

About 57 and 56 percent of the companies in the group of basic and intermediate advanced complexity, respectively, increased the field on environmental expenses in the last three years, which is very significant, as well the 34 and 30 percent of the plants at basic and intermediate advanced level, respectively, declared not to have modified the amount of their investment in the environmental area, which continue

to be relevant because the expenses prevailed. However, we find a little difference for companies of intermediate advanced level where such expenses diminished to 7 percent.

Unfortunately, the survey does not provide more information about which are the areas where companies allocate resources for environment protection, but indirectly we can assume that these investments are related to the areas which are positively impacted.

In this regard, we analyze the perception the directors of the assembly plants have about areas being positively impacted by the environmental measures implemented. The informants indicated the reduction in hazardous residuals as an important consequence of measures taken by them. This is significant because in terms of our regression analysis, we found that an important consequence of environmental investment of the assembly plants is the reduction of hazardous residuals, which is a main problem for them. Other areas that have been positively impacted by this investment are the "raw materials efficiency," and the performance of "permanent monitoring."

We found it very interesting that by one side, the companies declared that one of the main problems they are confronted with is the reexportation of hazardous residuals, and by the other, that 50 percent of the companies of the basic level and 45 percent of the intermediate advanced complexity level have taken measures and made investments to reduce such problem. Also, the bigger positive effects of those measures occur in the plants at basic and intermediate advanced techno-productive level. In both cases, such effects are associated with the efficiency of manufacturing processes as one of their main competitive advantages within their global corporative network. These positive effects may also be associated with both the observance of the normativity and a business opportunity when decreasing expenses of waste disposal. In this sense, the waste reduction is a result of the innovations made by the companies in the last three years.

As described above, the companies at basic techno-productive level concentrate themselves in activities of simple assembly, therefore, the processes of pollution and/or toxic substances disposal come more from the use of raw materials likewise solvents, acids, resins, soldering / welding, etc., than the production process itself. This situation is different from the companies at the intermediate advanced techno-productive level, which participate in processes of transformation and whose contact with polluting processes is more frequent.

According to Semarnat (http://wwww.semarnat.gob.mx/retc/principal3.html), in 2004, Baja California treated about 72 tons of hazardous residuals, and Chihuahua treated nothing, which is out of the ordinary if we consider that Ciudad Juárez concentrates an important number of assembly plants. In addition, Table 5 shows the total emissions and transfers between Tijuana and Mexicali for 2004. From this we can see that the emissions in Tijuana are greater compared to Mexicali, and it can be related to the fact that in Tijuana almost 50 percent of the assembly plants correspond to the basic productive level, in which assembly of parts and components, particularly in the electronic industry is important.

In the same sense as investigating more about the magnitude of the environmental issue, the companies were asked about the negative effects that the

Table 5. Total Emissions and Transfers by City, 2004

Location	Total Emissions (Water, Air, and Land)	Total Transfers (Reutilization, Recycling, Procedure, Treatment, Confinement and Others)
Mexicali	1.3456	2.557
Tijuana	12,276.7132	833.2341

Source: http://wwww.semarnat.gob.mx/retc/principal3.html

environmental measures instrumented had caused. The answers of the directors coincide with the excessive paperwork which means a sensible investment of time,[16] and the increments in its production costs. It seems difficult to calculate to which measure the production costs are increased starting from the investment in the environmental field.[17] As in the previous case, 50 percent of the basic companies and 44 percent of the companies at the intermediate advanced techno-productive level presented experienced negative effects. On account of the nature of the companies studied, it is understandable that those performing basic activities have been mainly affected by the changes implemented compared to those companies concentrating on tasks of transformation and with a greater level of organizational structure. In this context, the measures of environmental protection are observed as additional expenses that directly affect the companies' administrative costs.

With regard to the global corporative network, the plants at the intermediate advanced techno-productive level have as main competence the efficiency of manufacturing processes starting from the annual budget authorized by the corporation. Here, the competitive strategy is based on the quality and the efficiency of processes through the reduction of unitary costs of production and the reduction of dead times in the production line.[18] In this sense, such efficiency constitutes the main competitive advantage of those plants,[19] and the expenses associated with the environmental protection are observed in a way that is less harmful in relation to their main competences (the reduction of unitary costs in processes) because the environmental costs are redistributed based on unitary cost, allowing to tolerate a bigger administrative cost associated with the environmental control (García, 1999).

Certification Processes by Techno-Productive Complexity Level. The certifications in quality processes, such as the ISO 9001 and 9002, have an important impact on the environmental management process of the companies (Table 6). It is because the protocols that are followed to improve the product quality have less waste, have improved the use of technologies, have affected the environmental protection, and have generated a higher competitiveness for the company. In the analysis of such certifications, the companies decide to incorporate a determined quality management and/or environmental program in accordance with the nature of their industrial activity, the needs of their products, and the demands of their customers. Therefore, the certification in at least one program is for the set of companies studied, over 80 percent, which is a percentage worth of consideration.

Table 6. Certifications by Techno-Productive Complexity Level

Type of certification	Basic %	Intermediate Advanced %
ISO 9001	17.3	27.2
ISO 9002	30.0	38.4
ISO 14001	11.3	20.0
ISO 14002	0.7	3.2

Source: Idem. Table 1.

The certification in quality processes is unequal among companies with different levels of techno-productive complexity. For instance, among the companies at the basic techno-productive level we find that only 17 percent of them have been certified in ISO 9001, which is a relatively low percentage, and that 27 percent of the companies at the intermediate advanced level have such certification.

Other certification program that has a lot to do with the quality and relative relationship with environmental protection, and is apparently the most successful is the ISO 9002, those who count the 30 percent of basic level companies, and about 38 percent of intermediate advanced level. Concerning this, it is important to mention that one company can be certified in several programs at the same time. However, among the certifications that are closely related with the protocol of environmental protection are the ISO 14001 and 14002, in which a lot of companies do not take part yet, in spite of the fact that many of them declared having problems with the reexportation of toxic substances and the confinement of industrial waste.

We found that among the companies at the basic techno-productive level, at least 11 percent have adhered to the ISO 14001, as well as 20 percent of the companies at the intermediate advanced level. Regarding the ISO 14002, this is even less representative, which implies that the corresponding authorities have much left to do on the matter of environmental management, particularly among the companies from the intermediate advanced level. In fact, we found that 58 percent of the companies from the basic level and almost 57 percent from the intermediate advanced level affirmed that they do not have any ISO 14000 certification, which is too high.

An important issue in the survey was to explore what type of obstacles the companies are confronted with to manage ISO 14000 systems (Table 7), and we detect the following: The lack of knowledge on how to obtain certification was mentioned as the main obstacle, so declared by a little over 26 percent of plants at the basic level, and 36 percent at the intermediate advanced level. That is, the access to information about certification procedures continues to be an important obstacle for a good number of plants. Likewise, the inadequate financing to accede to this type of environmental management processes is considered a problem for almost 30 percent of the plants from the basic level and a little over 25 percent from the intermediate advanced techno-productive level.

Reasons to Protect the Environment and Main Actions Required. Other relevant aspect in the survey is regarding the reasons why the companies took measures in the

Table 7. Obstacles for Implementing the Environmental Management System ISO 14000 by Techno-Productive Complexity Level

Obstacles	Basic %	Intermediate Advanced %
Inadequate financing	29.8	25.5
Lack of well-trained technicians	14.0	21.3
Procedure to certification unknown	26.3	36.2
Lack of information about adequate technology	21.1	17.0
Other	8.8	0.0
Total	100.0	100.0

Source: Idem. Table 1.

Table 8. Reasons for the Introduction of Environmental Protection Technology by Techno-Productive Complexity Level

Reasons	Basic %	Intermediate Advanced %
By own decision	59.4	56.4
By needs of certification of the head office	13.3	24.8
By Profepa pressure	15.6	12.9
By other reasons	11.7	5.9
Total	100.0	100.0

Source: Idem. Table 1.

environmental scenario (Table 8). We found that 59 percent of the companies at the basic level and the 56 percent at the intermediate advanced level declared that they took measures of environmental control by own decision, however, we know that most of these companies have a strong dependence on their head office and/or subcontractor. On account of this, it is worth to mention that this decision is linked to market pressures.

Likewise, almost 25 percent of the companies at the techno-productive intermediate advanced level took the decision to introduce environmental protection technologies because their corporatists asked them to do so, although this reason only was mentioned by 13 percent of the companies at the basic level. As the assembly plants are pointed out as an industrial sector sensibly affecting the environment, the managers of these companies aim to modify their strategies, especially for not seeing their corporative image affected at international level and in the NAFTA scenario. Other reason mentioned to introduce new environmental technologies was pressures from Profepa, which was indicated by 16 percent of the plants at the basic level and by 13 percent at the intermediate advanced level, which refers a more vigilant action of the environmental protection authorities in the locality. To conclude this section, we analyze the opinion expressed by the directors of the assembly plants about the main changes that the companies consider should be introduced in the environmental policies that were instrumented by the government (Table 9).

On the one hand, without a doubt, the tax incentives are especially important for companies at the basic and the intermediate advanced level because such was considered by 46 percent and almost 37 percent, respectively. On the other hand, the

Table 9. Changes Needed in the Environmental Policies by Techno-Productive Complexity Level

Changes	Basic %	Intermediate Advanced %
Tax incentives	46.3	36.8
Administrative simplification	29.3	36.8
Environmental training policies	13.6	17.9
Others changes	10.9	8.5
Total	100	100

Source: Idem. Table 1.

administrative simplification was equally important for a little over 29 percent of the companies at the basic level and almost 37 percent at the intermediate advanced level, because, as already indicated, the companies expressed that they lose time and money with the bureaucratic paperwork. To conclude, for both groups of plants, the training policies in environmental issues are measures that should be implemented as support for a better environmental performance of the companies.

3.3. Environmental Performance Index

The EPI constitutes a summarized measure of the behavior of the visited plants regarding environmental issues and is based on the following variables: (i) existence or nonexistence of an explicit environmental policy of the corporation; (ii) expenditures allocated to the environmental protection[20]; (iii) implementation of the ISO 14001; (iv) existence or nonexistence of an environment department or environmental control unit; (v) personnel working on the environment department or environmental control unit[21]; and (vi) existence or nonexistence of cooperation among the plant and other institutions to solve environmental issues.

This index was built following some criterias: (i) The selected questions from the referred questionnaire were recoded as dichotomy variables and whose values are associated to the same score (1, 0). (ii) The evaluation regarding the environmental management is given in correspondence with the obtained scores in each variable. It is, while higher was the score, better than the evaluation. (iii) For the final calculation of the index, the scores were before added before for each one of the variables selected. (iv) Finally, each one of these results were divided by the sum of more value for the purpose of maintaining the index between 0 and 1, where the latter represents the possible higher environmental performance.

The analysis of the environmental performance observed in the visited plants suggests the existence of at least three differentiated groups: in the first one, we can find plants that have an environmental department, but that the proportion of people and expenses occupied in the environmental protection are low; the EPI embraces values which are from 0.22 to 0.25, representing 35 percent of the interviewed plants (119). In the second one, we find plants that have an environmental department, they maintain a proportion of personal expenses and environmental expenses greater than the previous group, also, they are certified plants in ISO 14001, they represent

42 percent (122) of the visited plants, and the evaluation of this indicator goes from 0.39 to 0.42. Finally, in the third one, we locate a group of companies whose main characteristic is a quantitative and qualitative improvement regarding the previous groupings; we refer to plants that are not only dedicating human and economic resources proportionally high with regard to the total number of resources in the plant, but also are certified in ISO 14001. Here, the values of EPI fluctuate between 0.5 and 0.57, representing 14 percent of the plants in the survey.

Regarding the institutional factors affecting the flow of economic and human resources intended to the environment (base of the calculation of our EPI), if we take as baseline that any activity having as objective the environmental protection has economic costs, it is additional to the normal expenses of a company and that, in addition, its exercise is as a result of a governmental action (through the application of the environmental regulations) and of the market (through the implementation of the ISOs); it results that the need the firms have to face the environmental problems derived from their activity is directly associated with the benefits and costs that this represents; either in terms of costs for failure to comply with the normativity or loss of image as company that is environmentally responsible. In this sense, the factors directly associated with the behavior of the demand for greater human and economic resources for the environmental management (demand of environmental management) would be related to the application of the normativity and to the environmental image the corporation wishes to have in its main market. As for our field observations, in addition to these factors, there are other elements of technical character that affect such behavior. We are talking here about the type of environmental hazard associated with the productive process and with its production scale related with the quantity of waste generated.

Regarding the degree of dependence or independence between the techno-productive levels and our indicator of environmental performance, we applied the "Chi-square" statistical test with a significance level of 95 percent. Contrary to what was expected by our work hypothesis and other previous studies (Carrillo et al., 2004; García Jiménez, 1999), the behavior of our environmental performance rate is statistically independent from the techno-productive levels. Regarding the environmental policy and resources (economic and human), variables associated with the productive evolution of our hypothesis, such as independence, is also observed.

The connotation of this statistical independence makes us suppose at least two behavior models: the first is related with the measurement criteria of the productive evolution (measured in this document through the techno-productive levels), and the second is related with the institutional and technical factors associated with the behavior of our environmental performance rate. Regarding the first behavior model, the criteria established as parameters of technological and organizational change are immersed in the discussion about the evolution that the assembly plants have had in the last 20 years. Therefore, there is consensus with regard to the capacity of productive, organizational, and technological evolution of the assembly plants, product of several assertions of labor, technological, industrial organization studies, and above all, of macro-visions recently developed (Barajas & Rodríguez, 1989;

Barajas et al., 2004; Brown & Domínguez, 1989; Carrillo & Hualde, 1997; Carrillo & García Jiménez, 2003; Dutrénit & Vera-Cruz, 2002; García Jiménez, 1999, 2002; González & Barajas, 2004; Montalvo, 2002, 2004). However, there is no unique consensus about theoretical concepts and the methodologies used to demonstrate such changes. Therefore, one speaks of evolutionary moments, productive generations, and, as we do in this document, techno-productive levels to express the dynamic behavior of the assembly plant, but without reaching a consensus about the nature of such changes.

4. Conclusions and Recommendations

The fulfillment of the normativity is the main cause to take actions of environmental protection, even if such behavior is differentiated in accordance with the techno-productive level: the companies at the intermediate basic level comply with the normativity because the head office demanded them to acquire their certification on environmental matter; those at the basic level introduced environmental technologies and measures because of the pressure of the Profepa, resulting in the conclusion that the companies with minor techno-productive development are less motivated to invest in environmental measures compared with more-developed plants.

More than half of the plants in the two levels argued to make investments in environmental protection by their own choice. It was a strategy to solve the environmental problems such as the confinement of industrial waste and the reexportation of toxic substances. However, in companies at the basic and intermediate techno-productive levels, the reduction of toxic material and emissions is the main positive effect of complying with the normativity.

The corporative environmental policy has a direct effect over the environmental behavior of the plants only when there is a need to obtain certification in compliance with the ISO 14001 or 14002 standards.

The strategies of quality and environmental management of the plants are associated with corporative policies, as well as the measures for reduction of waste as part of their activity in achieving efficiency of manufacturing processes, detecting here a direct association between the application of technologies for environmental protection and the advanced techno-productive level.

The relationship between the assembly plants and the governmental authorities is a result of the inspection process, and this is limited to administrative revisions of standards, therefore, this relationship is highly bureaucratic. The companies consider as negative effects of the environmental protection the loss of time because of excessive paperwork and the increment of production costs because there is little or no coordination among local, state, and federal authorities in charge with the control of environmental behavior. Half of the assembly plants are in favor of a greater administrative simplification.

The plants adhered to the federal program for *Voluntary Environmental Self-management* presented important qualitative and quantitative differences regarding the organizational structure on the matter of environmental management and the

proportion of human and economic resources allocated to it. There was detected an implicit interest from the management of the assembly plants to improve its organizational structure to comply with the normativity and improve its competitiveness, searching the acknowledgment of governmental authorities for its pro-environmental work. More than half of the plants that have ISO 14000 certification participate in the Voluntary Self-Management Program, which shows that the environmental behavior of these companies focuses only in complying with the national normativity on the matter and improve their corporative image in the international markets as company that is environmentally responsible. Likewise, the plants that have this type of environmental certification also have the ISO 9000 certification, therefore, the cognitive base of the plants to take measures of environmental protection under a formal organizational structure are directly associated with the formalization of their quality systems. The plants at the intermediate advanced techno-productive level are those presenting the best indicators, including the ISO 14001 and 14002 certifications.

Regarding the field of environmental expenses, the basic as well as the intermediate advanced level companies increased, in great measure, such expenses. That implies that both the developed and nondeveloped companies are taking care of a highly sensible area such as the environmental protection.

Three trends were detected through the EPI: (i) plants that have an environment department, but the ratio of people and expenses allocated in the environmental protection is low; (ii) plants that have an environment department, keep a ratio of personnel and environmental expenses higher than the previous group, and in addition, these are plants with ISO 14001 certification; (iii) companies whose main characteristic is a quantitative and qualitative improvement regarding the previous groups. Those are plants that not only allocate high human and economic resources proportionally in relation with the plant's total resources, but also have ISO 14002 certification.

Regarding the institutional and technical factors, their implementation is a result of the government's action (through the application of the environmental normativity) and the market (through the implementation of the ISO's); therefore, the need that the companies have to face the environmental problems derived from their activity is directly associated with the benefits and costs that this represents; either in terms of costs for failure to comply with the normativity or loss of image as company that is environmentally responsible.

There is yet a lot to do for most of the plants to decide to or to be pressed to obtain a certification under such standards, and this is also a pending task of the local, state, and federal authorities. There are serious limitations for the governmental institutions to promote the implementation of certification of environmental management, ISO 14000 type. One of them is that the governmental entities observed with some distrust the fulfillment of the standards in those plants that are certified, because in strict terms, this type of certifications only demands a "compromise to comply with the law," but does not force to comply 100 percent at the moment to obtain the certification. Furthermore, the fact that the governmental agencies do not participate directly in the certification process, but through a

private institution, increases the distrust in the normative fulfillment of this kind of companies.

Against all odds, the behavior of our environmental performance rate is statistically independent from the techno-productive levels.

It is necessary to design new mechanisms to overcome the limitations faced by the companies in the certification process because the main problem is the lack of information about proper technologies and the lack of knowledge of the procedures for certification on environmental matter, which makes an important task of the local authorities to inform and promote among the assembly plants their participation in processes of environmental management. It is required to implement environmental policies in the plants along with the allocation of an expenses item allocated to the environmental protection.

It is suggested to perform subsequent studies which allow to test the new hypotheses such as the demand for environmental management will be higher as the production upgrade and the type of environmental hazard associated go higher (technical factors), and at the same time, there is a high pressure to keep an environmental corporative image and a strict application of normativity. On the other side, a low demand for environmental management would be product of low levels of production, low pressure to comply with the normativity, and to keep an environmentally responsible corporative image.

More effective actions are required and an inter-institutional cooperation that at the same time control the fulfillment of the environmental normativity and improve the quality of service in the administrative paperwork is also required.

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Notes

1. The industrial upgrading is synonymous with the following terms used throughout this work: manufacturing evolution, techno-productive evolution, and techno-productive complexity levels.
2. We refer here to the environmental performance from the point of view of human and financial resources that the assembly plants allocate to the environmental protection.
3. This agrees with what was said by Schatan and Castilleja (2005) in the sense that the environmental problem goes beyond setting forth environmental regulations and making sure that these are complied.
4. In this document we understand as environmental behavior the set of actions performed by the productive agents for the environmental care. Among them is the application of environmental technologies to control and/or prevent the pollution generated by their activity.
5. In Mexico, the hazardous residuals are defined as "all residuals, no matter in which physical state, which characteristics have been corrosives, reactives, explosives, tóxics, inflammable or biological disease, and all of them represent a danger for ecological equilibrium or for the environment. The residuals could be defined as hazardous if they have been indentified and listed in the NOMs (Red Mexicana de Acción Frente al Libre Comercio & Texas Center for Policy Studies, 2000, p. 9).
6. As for Schatan and Castilleja (2005) some assembly plants are in better conditions than others to improve their standards of environmental protection, since their transnational corporations have that willingness. However, and in agreement with Wisner and Epstein (2005), the herein before mentioned is achieved as in such plants and their corporations, they are forced to comply with certain regulatory requirements of the countries where they manufacture and sell their products.
7. For us, the industrial upgrading is an ascending evolution of the techno-productive characteristics of the assembly plant. Its operationalization is made through the techno-productive levels which we identify as change parameters.
8. For further information, please refer to http://www.maquiladoras.info. This project number 35947 was financed by the National Counsel of Science and Technology (CONACYT).
9. A more detailed discussion about the issue is in Barajas, Rodríguez, and García, 2005, http://www.cec.org.
10. As a product of this restructuring, as for Stromberg (2004), between 1994 and 2000, there were recorded more than 3,383 resolutions against the assembly plants industry due to environmental violations, which translated into sanctions totalizing to 17.8 million pesos.
11. In this document, the application refers to the role that Mexican authorities play in the environmental protection, while the achievement refers to the role that the companies play regarding the follow-up of the provisions of the environmental regulations.
12. For a detailed analysis of the application and compliance of the environmental regulations, please refer to Mercado (2001), Muñoz (2004), and Stromberg (2004).
13. In addition that it is shown that the simple assembly and/or basic techno-productive activities continue to be a requirement of the global networks of production in which these industrial plants participate.
14. Unfortunately, this was the only case in which we could ran "principal components analysis" because of the difficulty to arrange information from the survey to do this precedure.
15. However, sometimes these organizations obtain some success by impeding the authorization of operation licences, temporal, and definitive closure of assembly plants.
16. Here, it is important to outline that even if the application of the normativity by the governmental requests is a relevant factor for the plants to adopt measures of environmental protection, it also generates a negative effect because of the nature itself of the fulfillment process.
17. Nevertheless, the costs increases derived from the implementation of measures did not result relevant (very probably because the diminishing of costs associated with the waste reduction). The beforementioned, because of the implementation of innovations in the process to reduce their waste in 91.3 percent (or 263) of the establishments visited.

18. See González-Aréchiga and Ramírez (1990), Alonso and Carrillo (1996), García Jiménez (1999), Contreras, Kenney, and Alonso (1998).
19. Some aspects to reduce their costs are the use of cheap labor, the savings in the payment of services (energy, water, and telephone), etc. While reducing the unitary costs of production, some ways that explore the assembly plant companies of this type are the reallocation of tasks on line, the search for new raw materials, the application of automated technologies and the implementation of new ways of organization.
20. The range of values corresponding to this variable was from 0 to 100.
21. The value of this variable was multiplied by the total number of employees, nonworkers who worked in the plant, that is, by the technicians, administrative personnel, and auxiliaries, and directors or managers. The variable considered for the calculation of the environmental performance rate was the total number of workers of the environment department weighed by the total number of employees who are nonworkers of the plant.

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