

Challenges for Cleaner Production in International Manufacturing Subcontracting

The Case of the Maquiladora Industry in Northern Mexico

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RESUMEN

En el ámbito global, las autoridades nacionales y locales enfrentan nuevas formas de organización industrial que hacen más difícil la regulación ambiental de estas actividades. Después de la última oleada de privatizaciones acompañadas de concentración económica en diversos sectores y de la maduración de la manufactura globalizada, se puede esperar que los organismos encargados de regular la actividad industrial tengan poca independencia y poder para diseñar y aplicar esquemas regulatorios. Éste es particularmente el caso en la promoción de innovación tecnológica encaminada a proteger el medio ambiente. Este artículo argumenta la tesis de que el ciclo de negocios en la industria maquiladora y la carencia de capacidad institucional de las autoridades ambientales regionales son las limitantes estructurales directas en la promoción de la producción limpia en la región fronteriza de Estados Unidos y México.

Palabras clave: 1. maquiladora, 2. innovación sustentable, 3. política ambiental, 4. subcontratación internacional, 5. México.

ABSTRACT

National and local authorities worldwide are facing new forms of industrial organization that impede environmental regulation of industrial activities. After the latest waves of public utility privatizations, accompanied by concentration in diverse economic sectors and the maturation of global manufacturing, it is to be expected that regulators might find themselves with little independence or power to design and enforce regulatory schemes. This is particularly true for the promotion of environmental protection through technological innovation in firms. This article argues that business cycles in the maquiladora industry and the institutional capabilities of regional authorities are direct structural constraints that inhibit the promotion of cleaner production in the Mexican-U.S. border region.

Keywords: 1. maquiladora, 2. innovation, 3. environmental policy, 4. international subcontracting, 5. Mexico.

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Fecha de recepción: 8 de abril de 2003

Fecha de aceptación: 24 de junio de 2003

INTRODUCTION¹

For more than 30 years, ever since the creation of the first environmental protection initiatives, the relationship between environmental agencies and industrial firms has been characterized by conflict. Since the 1990s, national and local authorities worldwide are facing new forms of industrial organization that impede environmental regulation of industrial activities. After the latest waves of public-utility privatizations, accompanied by concentration in diverse economic sectors and the maturation of global manufacturing, it is to be expected that regulators might find themselves with little independence or power to design and enforce regulatory schemes. This is particularly true for environmental protection promoted through technological innovation in firms. When promoting innovation, it is important to have a clear idea of the regulators' current institutional capabilities, which may limit their capacity to act, as well as to identify the structural rigidities of the industry in which behavioral change is sought.

This article examines technological and organizational structural rigidities related to manufacturing's evolutionary business cycles, and regional authorities' institutional capability to promote environmental protection. Both are direct structural constraints on the ability of firms to introduce innovative behaviors that would encourage clean production. The research conducted used as a case study the maquiladora industry located in northern Mexico. This industry is an *ad hoc* example of highly mobile firms, seeking optimally deregulated regions, and highly flexible labor, fiscal, and environmental regulations. Given that the study focused on firms that seek these conditions, the results of the study may be applicable to other countries or regions with similar contexts.²

This article begins with a brief overview of the maquiladora industry. Next, the dynamics of technological change in industrial manufacturing is outlined. The environmental management activities and the regulatory framework within

¹This article is based on a paper presented at the International Workshop on "Industrial Innovation and Environmental Regulation: Toward an Integrated Approach," United Nations University, Maastricht, Germany, October 2002. It also draws from the author's book, *Environmental Policy and Technological Innovation: Why Do Firms Adopt or Reject New Technologies?* Cheltenham, United Kingdom and Northampton, MA: Edward Elgar Publishing (2002).

²These factors have been widely studied elsewhere but are mentioned to illustrate the number of challenges that regional authorities would face in promoting technological change for environmental protection.

which the maquiladora industry operates are then critically analyzed. That is followed by a discussion of the method and findings concerning the maquiladora industry's evolutionary stages and firms' willingness to engage in innovative activities. The article concludes with a discussion of the challenges faced by the region's environmental authorities, and policy suggestions to promote cleaner production.

THE MAQUILADORA INDUSTRY

The maquiladora industry along the U.S.-Mexican border has been widely studied (*e.g.*, Godínez and Mercado, 1994; González-Aréchiga and Ramírez, 1990; Icasa, 1993; Taylor, 2000, De la O, 2000; Buitelaar and Padilla, 2000). The maquiladora industry appeared in northern Mexico in 1965 as part of the Program of Border Industrialization (Taylor, 2000). Since then, the region has become one of the world's most dynamic export platforms, with an industrial growth rate averaging over 15% per annum during the 1990s (Godínez and Mercado, 1994). Most of this growth stems from the relocation of factories from the United States and Japan along the entire U.S.-Mexico border.

Firms have continued to relocate their operations based on the attraction of 1) cheap, highly qualified, and virtually non-unionized labor; 2) tax exemption for inputs and revenues; 3) land subsidies; 4) low costs for services and infrastructure; 5) the proximity to the firm headquarters and markets in the United States; and 6) economies of agglomeration (González-Aréchiga and Barajas, 1988; Taylor, 2000; Koido, 2000).

Lax enforcement of environmental regulations has probably also played a part in this industrialization process. At its outset, the Border Industrialization Program comprised only 65 factories, generating 3 000 jobs along the border. By 1984, there were 672 factories (Carrillo, 1986), and by 1998, 3 833, generating 1 003 918 jobs (INEGI, 1998). The maquiladora industry is segmented into 10 sectors: auto parts; *textiles*; chemical products; electrical and electronic consumer and intermediate goods; food processing; timber and furniture; leather products; plastics; services; and tools and metal-mechanics (González-Aréchiga and Barajas, 1989).

The number of sectors and the rate of growth clearly convey the industry's dynamism and heterogeneity. Heterogeneity also exists in terms of productivity

and sophistication of the production processes in firms. These range from 1) very simple and old-fashioned assembly lines to long and complex manufacturing processes; 2) rigid, standardized, and intensive forms of labor employment to flexible labor and flexible automation; 3) small local factories to regional centers of production (Godínez and Mercado, 1994); and 4) firms that operate with no environmental management considerations to firms that have environmental management groups.

Although relocation funded by direct investments has occurred frequently, the maquiladora industry operates primarily within a “shelter” scheme, which is an intermediate strategy while a firm becomes familiar with the culture, regulations, labor, and politics of the host country. In a shelter scheme, the firm receives certain services from a Mexican contractor, which may include obtaining licenses and documentation, labor recruitment, construction of facilities, installation of production lines, plant management, and the securing of import and export permits.

Although maquiladora industrial development represents a partial solution to the problem of unemployment in the border region, its operations—similar to programs in a number of southern Asian countries (Gassert, 1985:46)—generate only low added value, minimal integration of national inputs (less than 2%), and zero technology transfer (Icasa, 1993; Carrillo, 1986), and they tend to cause regional wage contraction. In addition, because industrial relocation to the border region encourages rapid urbanization and population expansion, state and local governments are frequently unable to provide basic public services, causing many labor and environmental-health issues (Ganster and Sánchez, 1998). Some of these are related to the improper disposal of hazardous and solid wastes, industrial wastewater discharges, pollution of underground drinking water, and so on (*cf.* Kopinak and Guzmán, 2000; Mercado, 2000; Ganster and Sánchez, 1998; EPA, 1996; Álvarez and Castillo, 1986; Baker, 1989, 1990; Carrillo, 1986; Franco, 1991; Montalvo, 1992; Mendez Mungaray, 1995; Perry *et al.*, 1990; Sánchez, 1990a, 1990b, and 1991).

Although a regulatory framework for the operation of this industry exists, in many cases, local and state authorities have to choose between environmental quality and employment. This dilemma is a consequence of the way this industry operates. Most firms enjoy the services of industrial holding companies that provide shelter plans, which include the management of facilities, production, labor, transportation, and import-export services (González-Aréchiga and Ramí-

rez, 1990; Godínez and Mercado, 1994). Relative to other industries, maquiladoras present a high rate of openings and closures, as many firms are established for specific, short-term production projects. Additionally, to attract investment, local authorities must compete not only with other countries but also with other states within Mexico. Thus, the prevalence of easily cancelable shelter schemes and intra-regional location opportunities grants an even greater degree of negotiating power to already highly mobile (multinational) firms.

It is precisely at the time of any policy negotiation that stakeholders from government and industry should attain a better understanding of what is being negotiated and of what is and what is not possible to do, particularly with regard to environmental protection and sustainability goals. This is necessary in order to devise viable environmental policies to promote these goals. Whether maquiladora firms have a capacity to contribute to regional sustainability can be best analyzed from the perspective of the dynamics of technological change and industrial evolution. This approach reveals the sources of technological and organizational structural rigidities in industry that might hamper change toward more environmentally benign behaviors.

THE DYNAMICS OF TECHNOLOGICAL CHANGE IN INDUSTRIAL MANUFACTURING

Because technology is believed to be the central tool for responding to the challenge of sustainability (*e.g.*, OECD, 2002; EPA, 1996; PCSD, 1999; CSIS, 1997; MPWC, 1999; Iarrera and Vickery, 1997), it is necessary to discuss how technology evolves and intertwines with the logic of industrial organization. This evolution can be viewed from at least two perspectives: the macro, which examines paradigms that determine the direction of technological progress, and the micro, which considers the evolutionary stages through which firms pass.

Paradigms and Trajectories of Technological Change

At the macro level, the school of evolutionary economics has shown that technological change has its own inner logic (Nelson and Winter, 1977:56). Following Giovanni Dosi, at the core of any technological development is a *technological*

paradigm.³ Once a technological paradigm is fixed, it determines and conditions the evolution of technologies in specific and selected directions, termed *technological trajectories* (Dosi, 1982). The dominance of a particular technological trajectory is determined by evolutionary improvements that have self-reinforcing effects. René Kemp and Luc Soete (1992) include among these the costs and the performance of products and production processes and their integration into a socioeconomic context that includes accumulated knowledge and skills, production capabilities, infrastructure, regulations and social norms, and people's lifestyles. Some examples of technological paradigms that have followed definite optimization trajectories include: 1) automation; 2) speed in computer processing capacity; and 3) microelectronics.

The concatenation of diverse technological paradigms and trajectories form a *technological regime*. A technological regime represents a “set of design parameters which embody the economic principles that generate the physical configuration of products and processes and materials from which they are constructed” (Georghiou *et al.*, 1986:32). The technological regime is a framework shared by the totality of engineers, technologists, and economic actors as a basis for the search for improvements in production processes and products (Kemp, 1994) and for economic opportunities. As the technologies required to maintain marketplace competitiveness become more complex and expensive to research, develop, and perform, intra- and inter-firm trade also becomes more complex.

Intra- and inter-firm trade offsets to some degree the costs and risks involved in production and innovation, and it increases a firm's flexibility to cope with drastic changes in the demand for products (Tirole, 1988; Schoenberger, 1990). Hence, industrial organization develops into an interdependent chain of value creation, making the possibility of environmental sustainability a phenomenon that involves not only the firm or sector undertaking technological innovation aimed at clean technologies but also the entire industrial supply chain.

³A technological paradigm has been defined as “a pattern for the solution of selected techno-economic problems based on highly selected principles derived from the natural sciences. Therefore, it defines contextually the needs to be fulfilled, the scientific principles used for the task, the material technology to be used. A technological paradigm is both a set of exemplars—basic artifacts which are to be developed and improved and a set of heuristics—Where do we go from here? On what sort of knowledge should we draw?” (Dosi, 1988:225).

Cycles of Manufacturing Industry Evolution

At a micro level, an industry's degree of evolution and maturity at any given moment is intrinsically linked to the evolution of technologies required for the manufacture of a competitive product. William Abernathy and James Utterback (1975) characterize as cyclic the form of industrial manufacturing innovation in which products and production processes co-evolve. The cycle begins with a hectic generation of product and process concepts, which eventually reach maturity and decline and are finally replaced by a new wave of product and process concepts.

Utterback (1994) further refined the three main phases that make up this cycle. The first, "fluid" phase is characterized by the development of the concepts for both the product and the production process. In this phase, the rate of product innovation is rapid, with frequent and major changes in the product features. Diverse and often customized designs for the same product frequently coexist. The primary source of innovation is generally located within the firm that pioneers the product. Here, however, the research and development (R&D) effort is somewhat diffuse because of the very nature of new product development, in which the operational specifications it seeks to impart to the new product (and which define its novelty) require technical solution *for the first time*. Plant facilities are generally small, with flexible but inefficient production processes due to the use of general-purpose equipment and highly skilled labor. Major changes in production lines can be accommodated easily at a relatively low cost. The end of this phase is marked by the emergence of a product design that wins customer loyalty in the marketplace. The pioneering firm normally reaps the benefits arising from the novelty of its product as a result of the timing of its entry into an existing market or the creation of a new market with no competitors. Consequently, competitors and new entrants in the same industrial sector must adhere to the dominant design if they are to gain a significant market share.

The second, "transition" phase is distinguished by diminishing product innovation, and its replacement by frequent changes in the production process. In this phase, at least one product design has achieved the stability needed to obtain a significant market share and sufficient production volume to meet further rises in demand. At this stage, the major sources of innovation are the

manufacturers themselves and suggestions from the product's users. Further research and development efforts focus on specific product features. Plant facilities are generally of medium size, with the automation of some parts of the production process creating “islands” of automation; and major changes in production can be accommodated at moderate cost. At the end of this phase, the numerous firms struggling for a market share will rapidly give way to competitive pressures.

The third, “specific” phase is defined by a leveling off of the rate of innovation and the slowing of technological change in both the product and the production processes. Products become standardized and process improvements focus almost exclusively on productivity and quality. The sources of innovation at this stage are mainly the suppliers of components, machinery, and equipment. Research and development efforts focus on incremental changes in technologies in both the product and the production process, the emphasis being on the latter. Plant facilities are large, efficient, capital-intensive, and rigid, with purpose-built machinery and equipment that is mostly automated. Labor activity is primarily focused on tending and monitoring this equipment. The cost of major changes to the product or the production process—that is, to their concepts and design—is, therefore, very high. Normally the number of competitors is low, a classic oligopoly with a stable market share.

In summary, the evolution of an industry and its associated technologies revolves around a technological paradigm, in which firms struggle to survive in an environment of competitive selection driven by market laws. The evolutionary path proceeds through fluid and transitional phases, arriving ultimately at the specific phase, characterized by a dominant and rigid design. Once a product is in the specific phase, the technological paradigms underlying the dominant designs provide the direction in which the technological trajectories for products, production processes, and industries evolve. Such paradigms and trajectories have a powerful exclusionary effect. Blind to other needs and possibilities, the creativity and efforts of engineers and entire organizations are concentrated in rather precise directions (Dosi, 1982). As a consequence, technological “progress” follows certain trajectories due to any number of marginal evolutionary improvements, including, for example, the cost and performance of the design and its integration into a socioeconomic context based on accumulated knowledge and skills, production capabilities, infrastructure, regulations, social norms, and so forth (Nelson and Winter, 1977:56-59; Kemp, 1994).

*RECENT BORDER ENVIRONMENTAL MANAGEMENT:
AN ANALYSIS*

We have briefly examined the maquiladora industry, its relationship to the degradation of the Mexico-U.S. border environment, and the dynamics of technological change within which it operates. Now we can attempt to explain why failures in enforcement persist despite the existence of environmental laws and regulations at the local, state, and federal levels. Notable is the absence of policies directed at promoting environmental sustainability in the region, and hence, the failure to address the difficulties in shifting firms toward technological strategies that would promote sustainability.

The first modern Mexican environmental law, the *General Law on Ecological Equilibrium* (*Ley general de equilibrio ecológico*) was passed in 1971 (DOF, 1971), and it was revised in 1982, 1983, and 1988, under the title of *General Law on Ecological Equilibrium and Environmental Protection* (*Ley general de equilibrio ecológico*, LGEEPA). Although the 1988 version of the LGEEPA is the most stringent and comprehensive to date, significant loopholes remain, particularly with regard to the limited number of specific standards for a wide range of economic activities. Concern with the environment in the border region reached the political agenda in 1983, when the Mexican and U.S. governments signed the La Paz Agreement, creating a framework for binational cooperation to address issues of common concern in the region (Franco, 1991). The advent of NAFTA reinforced the environmental agenda. Common concerns over the border environment have led to the implementation of several initiatives and the founding of institutions (for example, the Integrated Environmental Plan for the U.S.-Mexican Border Area-Plan Integral Ambiental Fronterizo [PIAF] [Sedue-EPA, 1992]; Commission for Environmental Cooperation [CEC]; Border Environmental Cooperation Commission [BECC]; and North American Development Bank [NADBank]).

Despite the efforts of the local, state, and federal authorities to control and prevent the degradation of the environment in the border region, an analysis of past and current initiatives reveals that proposed solutions to environmental problems present many pitfalls. Concerning the enforcement of pollution-control policies, local, state, and federal authorities on the Mexican side of the border are as yet incapable of managing many of the delicate problems that afflict the region. Strong group interests hamper the success of environmental policy enforcement. Most of the appointments of senior officers and middle-manager

positions in the environmental agencies are determined more by political interests than by skills in science or engineering, resulting in a severe lack of organizational, institutional, and technological capabilities that hinder environmental protection (Table 1).

TABLE 1. *Shortcomings in Regional Environmental Management Capabilities*

Institutional capabilities

- a) The responsibilities of state and municipal governments are poorly defined because the environmental laws for most border states are general in nature. This vagueness sometimes results in overlapping functions or inaction at both levels.
 - b) Municipalities and states are responsible for enforcement, but most regulations are weak and underdeveloped.
 - c) Change in political administrations and lack of continuity in policies tend to reduce the likelihood of successful reforms.
 - d) Decision-making power and responsibility for environmental issues is unassigned.
 - e) At the local, state, and federal levels, inter-sector coordination (water, urban planning, solid waste disposal, etc.) is absent.
 - g) Smaller municipalities do not have environmental units.
 - h) Because of rent-seeking behavior by officials, violators find it easy and in their interest to pay a fraction of the stipulated fine as a bribe. Grossly underpaid enforcement officials are not only willing to accept bribes, they may even solicit them (Panayotou, 1993).
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Technological capabilities

- a) Municipalities are faced with insufficient and deteriorating infrastructures.
 - b) Excessive work demands on staff.
 - c) Inexperience and lack of technical knowledge.
 - d) Lack of laboratories and monitoring equipment.
 - e) Environmental management activities are, for the most part, extremely limited. Municipalities that have only recently incorporated environmental protection into their administrative agenda, those that count with environmental units, normally do not have a budget to operate those units.
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Sources. EPA (1996) and Panayotou (1993).

A main objective of the Plan Integral Ambiental Fronterizo was to assess the volume of hazardous and solid waste generated in the region (particularly, by the maquiladora industry), determine disposal methods used, and increase the capabilities for monitoring and enforcing regulations (Sedesol, 1990, 48-50). A comparison of these goals with the outcomes to date, as summarized in the PIAF Compendium of Activities (EPA, 1995) and with the recent developments in pollution control along the border, shows that the goals are yet to be achieved (see, for example, Wise, Salazar, and Carlsen, 2003). The authorities do not yet have the necessary capabilities to control and supervise the behavior of the industry on a regular basis (Table 1). Consequently, they do not know how much hazardous waste is being generated, what it comprises, or its possible effects on the environment.

According to the Compendium of Binational and Domestic U.S.-Mexico Activities and the Ministry of the Environment, Natural Resources and Fisheries (Semarnat) (see <http://www.semarnat.gob.mx/programas/-index.html>), an analysis of the 144 projects along the border shows that most research and other activities are related to the gathering of data on pollutants in the environment, risk assessments, best available end-of-pipe technologies, and best available recycling and waste minimization practices. In general, the focus is on remedial rather than preventive activities. Projects related to technical assistance include the promotion of new markets for end-of-pipe and solid waste management technologies. In terms of problem-solving efforts, there appears to be an overall lack of clear co-ordination among the regulatory agencies (both EPA and Semarnat) and industry.

The report of the CEC for 1998-2000 (CEC, 1999) and its agenda 2001-2004 (CEC, 2001) suggest laudable efforts on several fronts. The need to address the numerous urgent environmental problems leaves little space for the promotion of schemes that might encourage the development of clean technologies. A major problem that limits the potential of the CEC is its organizational size and budget, which is minimal considering its role as the promoter of cleaner technology in three countries and across *all* industrial activities. From 1998 through 2003, its budget averaged a mere US\$3 million per year.

Furthermore, the CEC's strategy of building pollution-prevention capacity through the creation of a fund is poorly defined. On one hand, there is the goal of obtaining funds from organizations with no real economic power, such as industrial associations and business councils. On the other, there is the working

definition of pollution prevention found in the CEC's action plans, which refers to the "minimization of wastes and its associated impacts" (CEC, 1999, 90), although some of its documents define it as "the avoidance of the generation of pollutants" (CEC, 1996a: 45). Consequently, the possible outcome of these poorly defined frameworks may be rather limited in regard to the great challenges entailed in the promotion of cleaner production in the maquiladora industry.

The agendas of the BECC and NADBank are intended to correct the deficit in the drinking-water supply and the wastewater-treatment infrastructure, improve the management of solid and hazardous waste, avoid impacts on the environment and bio-diversity, and increase urban infrastructure in the region. To date, however, these agencies have not proposed projects that involve industry or the modification of process and products (<http://www.cocef.org/>). In regard to promoting technological change in industry, the pollution-prevention program does not offer the possibility for active collaboration or connections with institutions like the U.S. Office of Technology Administration, the U.S. National Science Foundation, Mexico's Consejo Nacional de Ciencia y Tecnología (National Council on Science and Technology [Conacyt]), the Cámara Nacional de la Industria de la Transformación (Mexican Chamber of Industry [Canacintra]), and others (EPA, 1996).

Thus, it can be argued that the environmental law and its specific regulations, and the existing institutions that aim to promote pollution prevention are just "paper tigers." Most environmental protection efforts are directed towards pollution control, leaving schemes for pollution prevention through technological change outside the policy realm. As a result, a solution to environmental problems, not to mention sustainability, is seemingly remote.

STRUCTURAL CONSTRAINTS ON THE PROMOTION OF CLEAN PRODUCTION IN THE MAQUILADORA INDUSTRY

The author conducted empirical research to explore the structural constraints on the promotion of cleaner production in the maquiladora industry, with the goal of determining whether these firms are capable of contributing to regional environmental sustainability. This research also provided a baseline against which to contrast the scope of the efforts by regional environmental authorities and institutions to meet the challenge of environmental sustainability.

Methodology

Data used for the analysis were collected through the administration of a self-reporting questionnaire,⁴ which was used to survey firms. The firms were selected from the roster of Tijuana's Maquiladora Association (Asociación de Maquiladoras) and from listings provided by El Colegio de la Frontera Norte. The chief executive officer or highest ranking executive in 154 small and medium-sized manufacturing firms in the cities of Tijuana and Ciudad Juárez were contacted by a telephone call, followed by a personalized letter. These cities were selected because they have the greatest concentration of maquiladora firms on the U.S.-Mexican border. Ninety-seven questionnaires were included in the analysis.

Because of the maquiladora industry's heterogeneity, in order to achieve a higher representation, the criteria for industrial-sector selection focused on the relative degree of complexity of products and production processes and its relation to the length of its supply chain. Three sectors were selected: 1) electrical and electronics, which is assumed here to be the industry with the highest degree of product and production-process complexity and the longest supply chain; 2) metal-mechanics, which was considered to be moderate in complexity; and 3) plastics, which had the lowest complexity and shortest supply chain. These sectors were seen as representing the complexity of inter-firm trade along the supply chain of those sectors that make up the maquiladora industry. It was believed that the selection of these sectors might provide a sample with a gradient varying from high to low relative difficulty in terms of engaging in cleaner production (Figure 1). This would give an index that would include other industrial sectors that fall within the continuum.

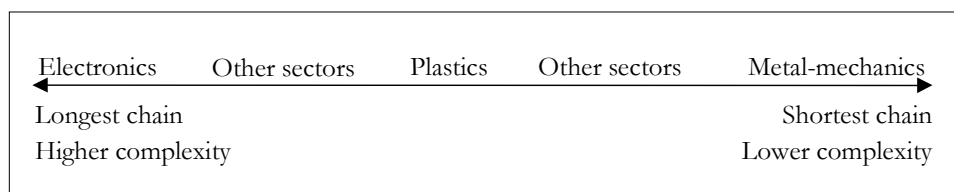


FIGURE 1. *Gradient of supply chain length and inputs composition complexity*

⁴Available from the author.

Stage of Industrial Evolution of the Maquiladora Industry

The firms in the sample are positioned at certain stages along the industrial evolution continuum. This characterization aims to provide an idea of the point of departure at which the firms in the sample might begin to move toward a clean production system. Following a framework proposed by James Utterback (1994), those manufacturing firms operating in the transitional or specific stages: of the product and process cycle could be expected to find it harder to move to a new technological regime.

Data analysis confirms that the main traits that characterize the maquiladora industry are its use of foreign operating capital and production oriented to exports to the U.S. market. For 88.7% of the firms in the sample, their capital originated in the United States whereas 11.3% got their capital from Europe and Asia. Almost all firms, that is 96.9%, exported more than 75% of their production, and 94.9% of the firms reported exporting their product to the U.S. market (Figures 2, 3, 4).

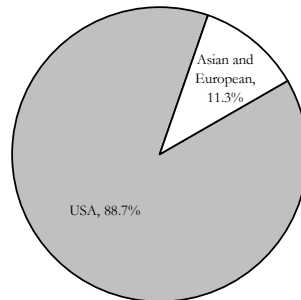


FIGURE 2. *Origin of capital*

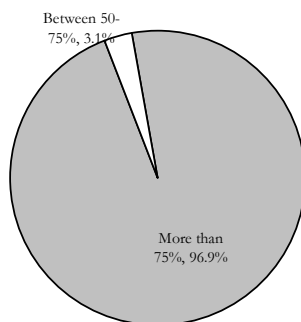


FIGURE 3. *Production exported*



FIGURE 4. *Export markets*

The sample was composed mainly of medium (56.7%) and small-sized firms (30.9%), with large firms accounting for only 12.4% of the sample (Figure 5). About half of the firms sampled (48.5%) were from the electronics sector, 36.1% were from the plastics sector, and 15.5% were from the metal-mechanics sector (Figure 6). It was expected that more firms with a strong willingness to develop clean technology would be found in the metal-mechanics sector, because it relies on simpler product and production processes and the shortest supply chain.

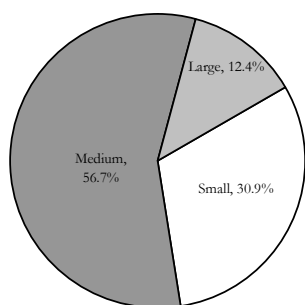


FIGURE 5. *Firm size*

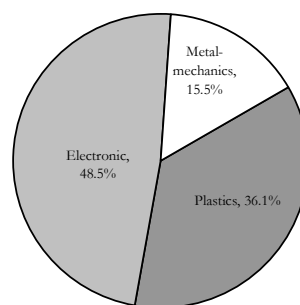
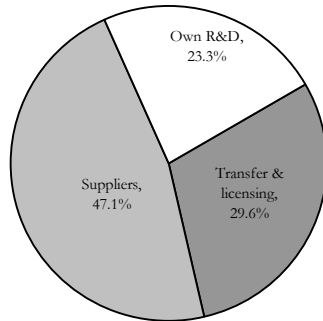
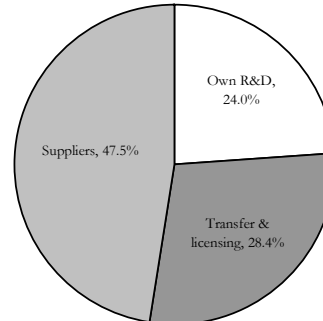
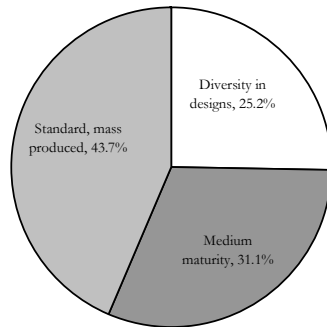
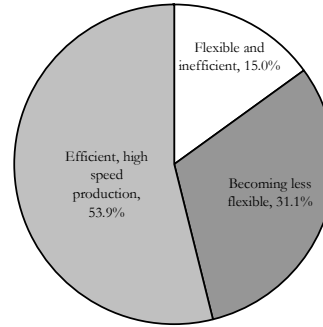


FIGURE 6. *Industrial sectors in the survey*

Regarding the *main sources of product and process innovations*, 47% of the firms reported being dependent mainly on suppliers of components and materials, 29% on transfer or licensing of new technologies, and 23% on their own R&D laboratories (Figures 7 and 8). Concerning *product maturity*, 43% had products were mostly undifferentiated and standardized, 31% had at least one product design that was stable enough to have significant production volume, and 25% had a variety of designs and often customized products (Figure 9). Similarly, with respect to *process maturity*, 53% had efficient, capital intensive, and rigid processes; 31% had processes that were becoming more rigid, with changes occurring in major stages of the production line; and 15% had flexible and inefficient processes, where significant change could be accommodated with reasonable ease (Figure 10).

Concerning *R&D activities*, 59% of the firms were focused on incremental changes in product technology, with emphasis on improving process technol-

FIGURE 7. *Sources of process innovation*FIGURE 8. *Sources of product innovation*FIGURE 9. *Product maturity*FIGURE 10. *Process maturity*

ogy; 37% were focused primarily on specific product or process features, and 4% had an undefined focus due to a high degree of technical uncertainty (Figure 11). Concerning the *type of machinery and equipment*, 47% of the firms had special purpose, mostly automatic equipment, with labor focused on tending and monitoring it; 35% had some islands of automation; and 18% had primarily general purpose equipment, requiring skilled labor (Figure 12). Of the respondents, 75% thought the *cost of technological change* was high, whereas 22.5% believed it to be moderate, and 2% perceived it to be low (Figure 13).

With respect to the *number of competitors*, 41% of the respondents indicated that a few companies dominated the market, 34% reported that the number of competitors was declining, and 24% reported having few competitors but that these were growing in number (Figure 14). Most respondents (63%) reported

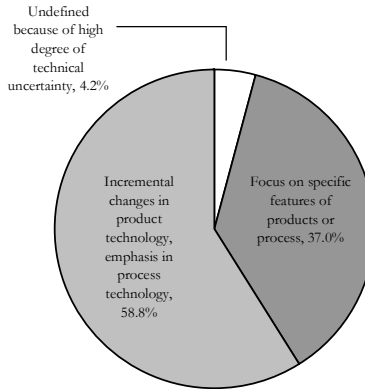


FIGURE 11. R&D activities focus

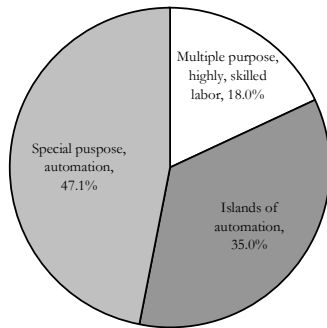


FIGURE 12. Type of machinery and equipment

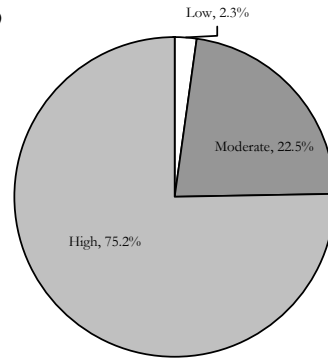


FIGURE 13. Cost of technical change

that their *competition strategy* was based on price and quality, 25% indicated competition based on product differentiation, and 11% on product performance (Figure 15). The last feature of interest was *organizational control*. The literature on innovation reports that firms with more informal and entrepreneurial organizational relationships are more innovative (e.g., Tidd, Bessant, and Pavitt, 1997; Leonard-Barton, 1995; Nonaka, Takeuchi, and Umemoto, 1996). Just under 60% of the firms reported that they were in the specific phase, that is, they described their labor relationships as being based on structures, hierarchies, and procedures; 21% reported operating team projects; and 19% described their organization as informal and entrepreneurial (Figure 16).

In sum, the data regarding the evolutionary stage of the industry show a frequency of responses that indicates that the sampled firms operate predomi-

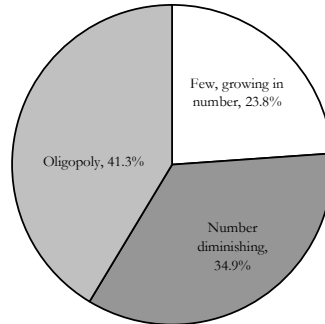


FIGURE 14. *Number of competitors*

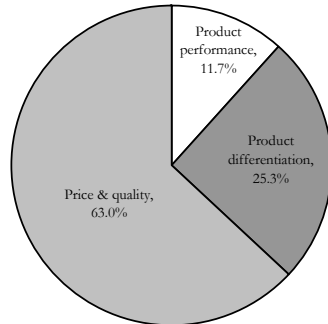


FIGURE 15. *Main competition strategy*

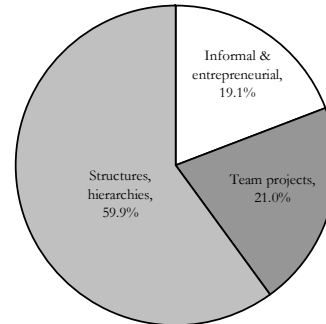


FIGURE 16. *Type of organizational control*

nately in the specific phase of product and process evolution. An analysis of the data indicates that approximately 55% of the firms exhibit some traits of the specific phase, 29% reported having transitional phase features, and 16%, features of the fluid phase. Based on the characteristics of these sectors within the maquiladora industry, it had been anticipated that a greater number of firms would be found to operate within the specific phase. However, although many managers identified their firms as having primarily specific-phase features, they still reported some features of the transitional and fluid stages. Despite this blurring of distinctions among respondents, most firms in the sample reported features of product and production processes that clearly suggest that the firms will find it difficult to make radical changes to move toward clean technologies.

Sectoral Differences and Willingness of Firms to Engage in Clean Production

At first glance, the most flexible industrial sector—although not by much—appears to be metal-mechanics (Figure 17). For firms in that sector, the source of innovations in product and processes is predominantly their own R&D capacity, and they have moderate to high flexibility in their current machinery and equipment. They are less dependent on suppliers of materials and components than firms grouped in the plastics and electronics sectors. In addition, metal-mechanics firms face a larger number of competitors and operate with structures of organizational control that are relatively less rigid. Some firms in the electronics sector reported that their innovative activities include radical design changes. The three sectors seem to share the feature of high costs for radical technological change.

In general, the data support the notion that firms with a long supply chain will be likely to be more rigid, which thus might make it more difficult to

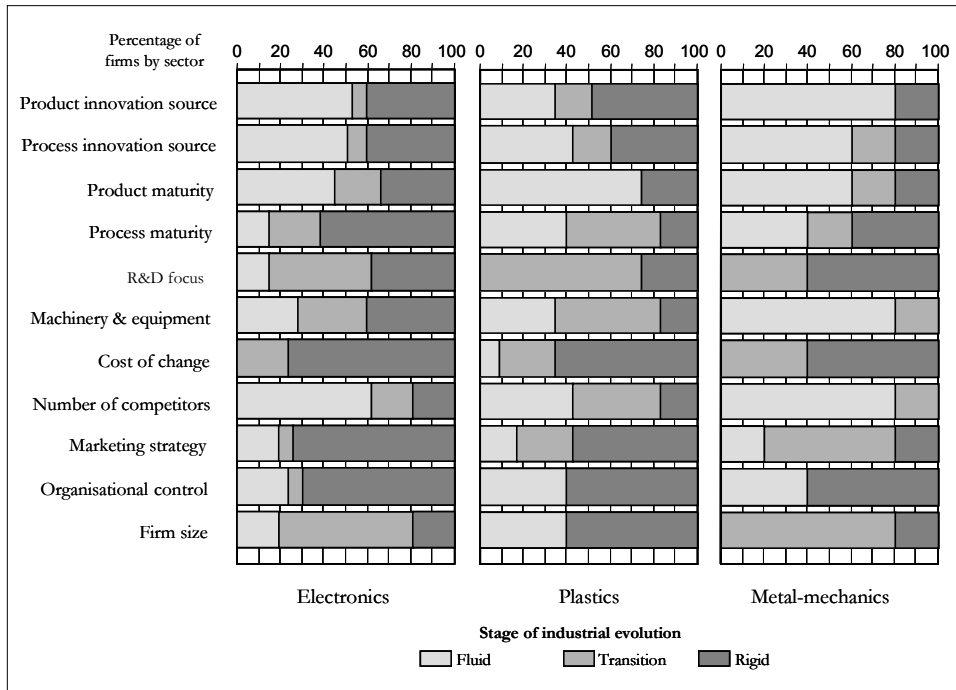


FIGURE 17. *Stage of industrial evolution by sector*

engage in radical innovation towards clean production (Figure 17). Similarly, it was expected that firms in the fluid stage would be more willing, and find it easier, to develop clean technologies. An example of this stage was the metal-mechanics sector, with its relatively simple materials composition, product and production processes, and a short supply chain.

Contrary to expectations, the data do not support this assumption (Figure 18). On average, the three sectors surveyed reported they were unwilling to introduce innovation that would encourage clean production.

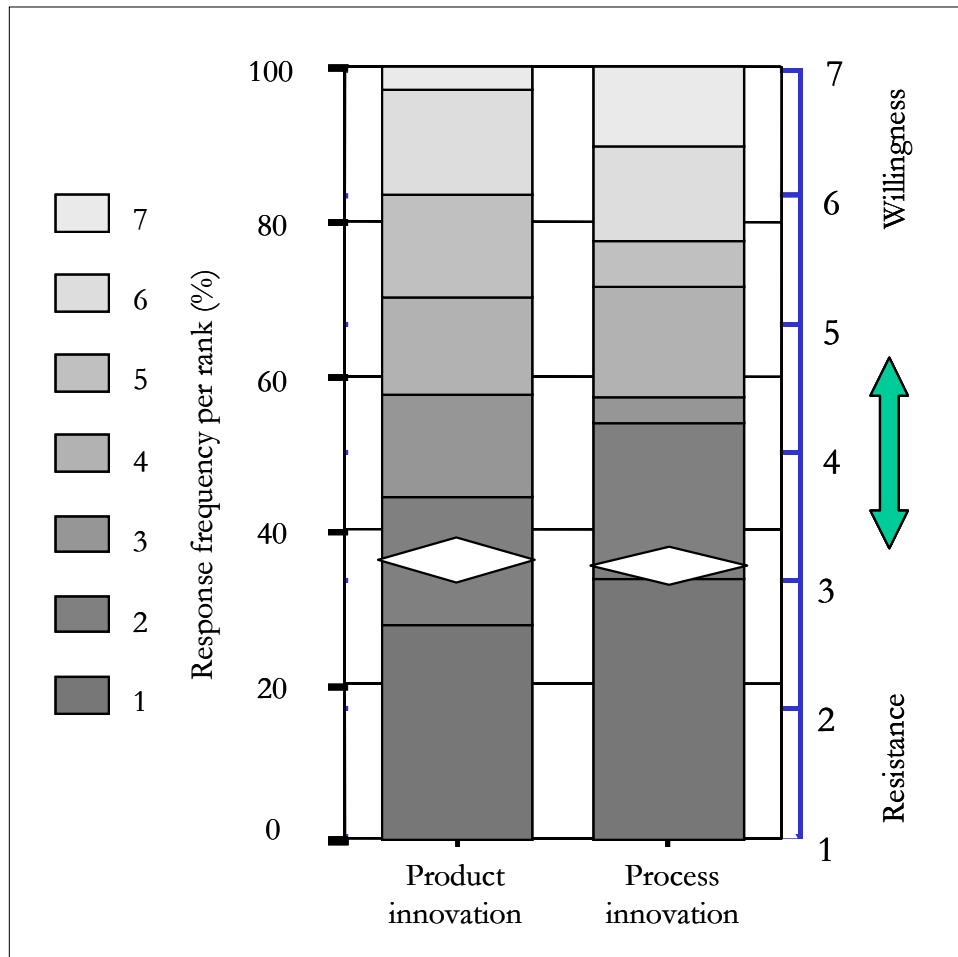


FIGURE 18. *Willingness to develop clean technologies*

This sectoral comparison suggests that, on average, the firms in the sample face similar realities concerning the development of clean technology. Despite minimal disparities in the different sectors' scores for willingness to innovate, it can be argued that the most flexible sector is the least willing to engage in innovation for cleaner production. This is perhaps an indication that firms in this sector are finding it more difficult to change because they will receive fewer benefits from innovative activities or because they are facing weak social pressure to engage in pro-environmental innovations. Similarly, contrary to the initial assumption, firms grouped in the electronics sector are more willing to innovate than those in the metal-mechanics sector, but they are less willing to innovate than those in the plastics sector.

The apparent disparity between the sample's evolutionary stages and willingness to innovate might be explained by the diverse realities and problems that firms face. These include economic and environmental risks, market constraints, community and regulatory pressures, and limited technological and organizational capacity to introduce environmentally sound innovations.

CHALLENGES TO DESIGNING AND IMPLEMENTING POLICY FOR CLEANER TECHNOLOGY

This section summarizes the discussion above and proposes some policy initiatives aimed at enabling the creation of a minimal technological and institutional “soft” infrastructure to face the challenge of clean production in the region's maquiladora industry. Taking the sampled firms as representative, most maquiladoras are in the specific phase of their industrial evolution (Figures 7 to 13). Because their activities are focused mainly on standardized mass production, the source of product and process innovation is principally suppliers, and the firms focus their R&D efforts primarily on marginal changes in process efficiency and cost reduction. It can be expected that the firms in the sample will find it extremely difficult to shift into a new technological paradigm because of not only the focus of their own innovative activities but also their dependence on suppliers of inputs, components, machinery, and equipment for technological changes.

The nature of maquiladora industrial organization further poses limitations for policy design directed at promoting innovations. Common features for all

maquiladora firms include foreign investment, high geographic mobility, high rates of openings and closures, and tax-exempt revenues (because maquiladora operations in Mexico are considered to be cost centers). The question of how to promote and facilitate technological change that would both benefit the firms and protect the environment presents additional challenges. For example, these firms already enjoy subsidies through low wages and tax exemptions, which enhance their international competitiveness. Any investment by the Mexican government to promote R&D and innovation would only increase the level of subsidies. In addition, because these firms are costs centers, local-level decision making regarding radical technological changes is constrained. Ultimately, the overall technology strategy is linked to marketing, and the growth of the firm is defined at its headquarters, which often lies beyond the national boundaries of the country in which the manufacturing plant is located. Environmental institutions and regulatory agencies charged with environmental management along the U.S.-Mexican border are finding it difficult to cope with current problems. Most of the current activities are related to control and remediation of pollution. Very little attention is given to policies that promote pollution prevention, and there is no awareness of the importance and implications of the dynamics of technological change for environmental policy design.

Thus, the technological component of current environmental policies is poorly defined, and the corresponding efforts remain unfocused. This occurs partly because of the evolutionary stage and industrial organization of the maquiladora industry. It also occurs because regulatory agencies and institutions lack the technological and organizational capabilities needed to promote clean technology along the U.S.-Mexican border. Certain policy suggestions may be able to ease these shortcomings.

Policy Suggestions for Building Clean Technology Capacity

It is necessary to create an institutional infrastructure and mechanisms to accumulate clean technology capabilities in northern Mexico. Given the realities for the maquiladora industry and the regional regulatory scheme, the following policy suggestions focus on the “soft” component of the innovation diffusion process. Here “diffusion” refers to the “process by which an *innovation* that is, the clean technology concept) is *communicated* through certain channels over

time among the members of a *social system*” (Rogers, 1995). Therefore, the activities considered here focus on the promotion of a better understanding of what clean technologies are, their possible economic benefits to the firms, and the management methods employed to implement technological and organizational change in firms.

First, we anticipate that creation and implementation of capabilities for environmentally sound clean technologies will be a lengthy process, involving the participation of wide and heterogeneous sectors of society, such as legislators, firms, government, academia, the community, and financial institutions. To promote the participation of several sectors, it is necessary *to create a U.S.-Mexican binational agency or task group designed especially to merge the efforts of environmental agencies, academia, and industrial chambers into a body that enables the generation of synergies*. This recommendation arises from the necessity to involve “champions” at the highest level of the corporate boards of industry, as this group has been absent in all environmental initiatives along the U.S.-Mexican border. The BECC and CEC already provide examples of such agencies.

Second, the development of clean technologies for pollution prevention has gained currency as an important part of environmental policy (OECD, 2002). This approach is appropriate because it costs less to achieve real environmental protection in the long term, and it increases overall economic efficiency at the firm level. In addition, it has recently been recognized that cleaner products and cleaner production technologies can become a new multiplier of economic growth in those countries that endorse and promote this paradigm. This is particularly apparent in recent U.S., Canadian, and Japanese documents for technology policy and the environment (e.g., PCSD, 1999; U.S. White House, 1998; CEC, 1996a; Calleja *et al.*, 2002). Although this *vision*—that is, clean production as an economic multiplier—is mentioned in documents at the government policy level, many of the interviews carried out with the firms' managers revealed that the concept and the benefits of clean technologies—in terms of economic efficiency—are poorly understood. Therefore, it is necessary *to create a common vision with common goals through consensus mechanisms combined with information exchange among regulators and industry*. These mechanisms would include the regular organization of conferences and workshops to disseminate information about state-of-the-art environmental management systems and the long-term benefits of cleaner production for the firms, the community, and the environment on both sides of the border.

Third, it is interesting to note different approaches to the same problem. An analysis of policy initiatives reveals that whereas industry, government, and academia are closely connected in Japan and Canada, in the United States and Mexico, the linear model of technological “push” is still visible in documents that promote environmentally sound technological change (U.S. White House, 1998; EPA, 1998; MPWC, 1999). This model has already proved inefficient in promoting technical change because, very frequently, the results of basic research in universities and research centers fail to reach the industrial and commercial stage. Some initiatives are already in progress to address pollution prevention in the NAFTA region (CEC, 1999). Unfortunately, these activities have not included representatives from the maquiladora industry. Because of a history of conflictive relationships between industry and environmental agencies, any environmental initiative seen by the maquiladora industry as originating from “outside” likely will be met with distrust. Therefore, it is necessary *to promote applied research projects that connect academic institutions and environmental agencies to industry so that they can work together on specific problems of pollution prevention assistance.*

Fourth, along the border there already exists great potential in academic and R&D infrastructure, which has yet to be put at the service of applied research.⁵ These collaborations could generate immediate benefits for the firms that participate, and spin-off benefits for the community and other industries in the region. Assistance in developing cleaner technologies can occur at different response levels, depending a specific firm's evolutionary stage. Understandably, firms that have been known historically as “dirty” cannot begin the complete redesign of their products and processes, especially when the core problem in their perceived capabilities lies in the very nature of their products. *In this regard, the agreements between industry, academia, and environmental agencies should explicitly differentiate and aim to provide—at various response levels—assistance to firms in developing cleaner technologies.*

Fifth, few of the managers interviewed were aware of the concept of clean technology. The knowledge and tools for innovating are lacking in most firms. Additionally, the region lacks professional consultants or companies that provide services in EMS implementation and innovation management. This training is absent in the curricula of the region's professional education system. *There-*

⁵The Mexican side of the border has seven state universities (with many campuses), 12 federal technological institutes, and several prestigious private universities.

fore, it is necessary to coordinate regulation activities with the Ministry of Education to promote the creation of an infrastructure to train people so that the human resources required are available to provide services and assistance in creating future pollution prevention programs in firms.

Last, reinforcements in form of local rewards and social norms have proven important motivators of individual behavior (Ajzen 1988, 1991; Cross and Guyer 1980; Higgins and Kruglansky, 1996). *Therefore, an effort must be made to institutionalize local reinforcements and social recognition for the firms (or managers) that make significant environmental improvements.* Mechanisms for and experience in how to create awareness and social desirability of a specific activity are abundant, including such things as prizes, titles, honorary positions, special mentions, and so forth. The feature common to all these rewards is the generation of social recognition and status. The existence of short-term rewards, which would signal that innovations reap short- and long-term benefits, could increase the social desirability of technological change for cleaner production.

In summary, from the limitations imposed by the stage of industrial evolution of the sampled firms, coupled with environmental authorities' lack of attention to pollution prevention, arises the need to create a basic institutional infrastructure. The task of these institutions would be to promote the concept of clean technology and the deployment of knowledge about available technologies and innovation management tools. We could expect that the creation of this institutional infrastructure, in conjunction with activities designed to raise the environmental awareness of firms, would trigger a virtuous circle leading to greater willingness on the part of firms in the maquiladora industry to improve their environmental performance.

FINAL REMARKS

This article has attempted to locate where the maquiladora industry stands on the road to creating environmental sustainability. It establishes a baseline against which to contrast the scope of the efforts being made by regional authorities and institutions in their attempt to meet the challenge of environmental sustainability. With the advent of global manufacturing, it can be expected that local regulators find themselves with little independence and power to design and enforce regulatory schemes and encourage firms to embrace environmen-

tally responsive innovations. This article has argued that firm's innovative pollution-prevention behavior is greatly constrained by the structural features of the current "techno-economic regime" within which firms operate. In other words, firms' strategies and behavioral change are strongly dependent on both the external (macro) and the internal (micro) dynamics of technical change rather than solely on positive environmental attitudes and values.

REFERENCES

- Abernathy, William J., and James M. Utterback, 1975, "A dynamic model of product and process innovation," *Omega International Journal of Management Science* 3 (6):639-656.
- Ajzen, Icek, 1988, *Attitudes, Personality, and Behavior*, Chicago, Dorsey Press.
- , 1991, "The theory of planned behavior," *Organizational Behavior and Human Decision Process* 50:179-211.
- Álvarez, Juan, and Víctor M. Castillo, 1986 (eds.), *Ecología y Frontera/Ecology and the Borderlands*, Mexico City, Universidad Autónoma de Baja California.
- Baker, George, 1989, "Costos sociales e ingresos de la industria maquiladora," *Comercio exterior* 39 (10):893-906.
- , 1990, "Mi Comida con Andrés: A Non-Traditional Approach to Fiscal Equity and Academic Collaboration in Northern Mexico," pp. 489-554 in *Subcontratación y empresas transnacionales: Apertura y reestructuración en la maquiladora*, edited by Benardo González-Aréchiga and J. C. Ramírez, Mexico City, El Colegio de la Frontera Norte-Fundación Friedrich Ebert.
- Buitelaar, Rudolf M., and Ramón Padilla Pérez, 2000, "Maquila, Economic Reform, and Corporate Strategies," *World Development* 28 (9):1627-1642.
- Calleja, Ignacio, Josefina Lindblom, and Oliver Wolf, 2002, "Clean Technologies in Europe: Diffusion and Frontiers," *The IPTS Report*, 69, Seville, JRC (Joint Research Centre)-IPITS (Institute for Prospective Technological Studies).
- Carrillo, Jorge (ed.), 1986, *Reestructuración industrial: Maquiladoras en la frontera de México-Estados Unidos*, Mexico City, El Colegio de la Frontera Norte-Consejo Nacional para la Cultura y las Artes.
- CEC (Commission for Environmental Cooperation), 1996a, *Status of Pollution Prevention in North America*, Montreal, Quebec, CEC.

- , 1996b, *Assessing Latin American Markets for North American Environmental Goods and Services*, report prepared for CEC by ESSA Technologies Ltd., GLOBE Foundation of Canada, SIAC de México, S.A. de C.V., and CG/LA Infrastructure, Montreal, Quebec, CEC.
- , 1999, *North American Agenda for Action 1999-2001*, Montreal, Quebec, CEC.
- , 2001, *North American Agenda for Action: 2002-2004*, Montreal, Quebec, CEC.
- Cross, John G., and Melvin J. Guyer, 1980, *Social Traps*, Ann Arbor, University of Michigan Press.
- CSIS (Center for Strategic and International Studies), 1997, *The Environmental Protection System in Transition*, Washington, DC, CSIS Press.
- De la O, M. E., and C. Quintero, 2000, "Las industrias maquiladoras en México: Orígenes comunes, futuros distintos," paper presented at the International Conference on Free Trade and the Future of the Maquila Industry: Global Production and Local Workers, El Colegio de la Frontera Norte-United Nations Economic Commission on Latin America and the Caribbean, Tijuana, Mexico, October 20-21.
- DOF (*Diario oficial de la federación*), 1971, *Ley federal para prevenir y controlar la contaminación ambiental*, March 23, DOF.
- Dosi, Giovanni, 1982, "Technological Paradigms and Technological Trajectories," *Research Policy* 11:147-62.
- , 1988, "The nature of the innovative process," in *Technical Change and Economic Theory*, edited by G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete, London, Printer Publishers, pp. 221-228.
- EPA (U.S. Environmental Protection Agency), 1995, *Compendium of EPA Binational and Domestic U.S./Mexico Activities*, EPA 160-B-95-001, Washington, DC, U.S. EPA.
- , 1996, *U.S.-Mexico Border XXI Program: Framework Document*. EPA 160-R96-003, Washington, DC, U.S. EPA.
- , 1998, *Stakeholder Attitudes on the Barriers to Innovative Environmental Technologies*, EPA 236-R-98-001, Washington, DC, U.S. EPA.
- Franco Barreno, René B., 1991, "Disposición de residuos industriales en la frontera: Posibles impactos del Tratado de Libre Comercio," paper presented for the Plan Integral Ambiental Fronterizo México-Estados Unidos, Ciudad Juárez, Chihuahua, Mexico, September 19.

- Ganster, Paul, and Roberto A. Sánchez, 1998, *Sustainable Development in the San Diego-Tijuana Region*, La Jolla, CA, Center for U.S.-Mexican Studies, University of California, San Diego.
- Gassert, Thomas H., 1985, *Health Hazards in Electronics: A Handbook*, Hong Kong, Asia Monitor Resource Center.
- Georghiou, Luke, S. Metcalfe, M. Gibbons, T. Ray, and J. Evans, 1986, *Post-innovation Performance: Technological Development and Competition*, London, Macmillan.
- Godínez, José Alberto, and Alfonso Mercado G., 1994, "Fuentes de eficiencia y de la competitividad en la industria maquiladora de exportación en México," Informe técnico de investigación para el Conacyt, Departamento de Estudios Economicos, Tijuana, B.C., El Colegio de la Frontera Norte.
- González-Aréchiga, Bernardo, and Rocío Barajas, 1988, *Las maquiladoras: Ajuste estructural y desarrollo regional*, working paper, Mexico City, Fundación Friedrich Ebert.
- , and Rocío Barajas (eds.), 1989, *Las maquiladoras: Ajuste estructural y desarrollo regional*, Tijuana, B.C., El Colegio de la Frontera Norte and Fundación Friedrich Ebert.
- , and J. C. Ramírez (eds.), 1990, *Subcontratación y empresas trasnacionales. Apertura y reestructuración en la maquiladora*, Mexico City, El Colegio de la Frontera Norte-Fundación Friedrich Ebert.
- Higgins, E. T., and A. R. Kruglansky (eds.), 1996, *Social Psychology: Handbook of Basic Principles*, New York, Guilford Press.
- Iarrera, M., and G. Vickery, 1997, "Clean Technologies," *OECD Observer* (June), 24-27.
- Icasa, L. P. A., 1993, "Marco teórico de la industria maquiladora de exportación," *Comercio exterior* 43 (5):415-429.
- INEGI (Instituto Nacional de Estadística, Geografía e Informática), 1998, *Estadísticas de la industria maquiladora de exportación*, Aguascalientes, INEGI.
- , 1999, *Estadísticas de la industria maquiladora de exportación*, Aguascalientes, INEGI.
- Kemp, René, 1994, "Technology and the Transition to Environmental Sustainability: The Problem of Technological Regime Shifts," *Futures* 26 (10): 1023-1046.
- , and Soete, Luc, 1992, "The Greening of Technological Progress: An Evolutionary Perspective," *Futures* 24 (5):437-457.
- Koido, A., 2000, "Territorialized Nexus of Transnational Production Chain and its disjunctive with local structure: Development of industrial agglom-

- eration of CTV in U.S.-Mexican Border and its Limits,” paper presented at the International Conference on Free Trade and the Future of the Maquila Industry: Global Production and Local Workers, El Colegio de la Frontera Norte-United Nations Economic Commission on Latin America and the Caribbean, Tijuana, Mexico, October 20-21.
- Kopinak, Kathryn, and Saúl Guzmán, 2000, “Industrial Hazardous Waste in Tijuana and its Proximity to Local Populations,” paper presented at the International Conference on Free Trade and the Future of the Maquila Industry: Global Production and Local Workers, El Colegio de la Frontera Norte-United Nations Economic Commission on Latin America and the Caribbean, Tijuana, Mexico, October 20-21.
- Leonard-Barton, Dorothy, 1995, *Wellspring of Knowledge: Building and Sustaining the Sources of Innovation*, Boston, MA, Harvard Business School Press.
- Méndez Mungaray, Elizabeth, 1995, “La industria maquiladora en Tijuana: Riesgo ambiental y calidad de vida,” *Comercio exterior* 45 (2):159-163.
- Mercado, A., 2000, “Comportamiento de las maquiladoras con respecto al cumplimiento de las normas ambientales,” paper presented at the International Conference on Free Trade and the Future of the Maquila Industry: Global Production and Local Workers, El Colegio de la Frontera Norte-United Nations Economic Commission on Latin America and the Caribbean, Tijuana, Mexico, October 20-21.
- Montalvo, Carlos C., 1992, *Costo ambiental del crecimiento industrial: Caso de estudio de la maquiladora electrónica en Tijuana, B.C.*, Mexico City, Friedrich Ebert Foundation.
- MPWC (Ministry of Public Works and Government Services, Canada), 1999, *Progress in Pollution Prevention 1997-1998: Annual Report of the Pollution Prevention Coordinating Committee*, Ottawa, Minister of Public Works and Government Services, Canada. Available at <http://www.ec.gc.ca/p2progress>. Accessed July 2000.
- Nelson, R. R., and S. G. Winter, 1977, “In Search for a Useful Theory of Innovation,” *Research Policy* 6:36-76.
- Nonaka, I., H. Takeuchi, and K. Umemoto, 1996, “A Theory of Organizational Knowledge Creation,” *Journal of Technology Management* 11 (7-8):833-845.
- OECD, 2002, *Technology Policy and the Environment*, Paris, OECD.
- Ojeda, M., 1995, “Presentación” in *Primer Foro del Ajusco: Desarrollo Sostenible y Reforma del Estado en América Latina y el Caribe*, edited by El Colegio de

México, Mexico City, El Colegio de México-Programa de United Nations para el Medio Ambiente.

- Panayotou, Theodore, 1993, "The Economics of Environmental Degradation: Problems, Causes and Responses," in *Environmental Economics*, edited by Anil Markandya, and Julie Richardson, London, Earthscan Publications, pp. 316-363.
- PCSD (President's Council on Sustainable Development), 1999, *Towards a Sustainable America: Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century*, Washington, DC, U.S. Government Printing Office.
- Perry, Diane, R. A. Sánchez, W. H. Glaze, and M. Mazary, 1990, "Binational Management of Hazardous Waste: The Maquiladora Industry at the U.S.-Mexico Border," *Environmental Management* 14 (4):441-450.
- Rogers, Everett M., 1995, *Diffusion of Innovations*. New York: Free Press.
- Sánchez, Roberto A., 1990a, *El medio ambiente como fuente de conflicto en la relación binacional México-EUA*, Tijuana, B.C., El Colegio de la Frontera Norte.
- , 1990b, "Otra manera de ver la maquiladora: Riesgos en el medio ambiente y la salud," pp. 553-570 in *Subcontratación y empresas trasnacionales. Apertura y reestructuración en la maquiladora*, edited by Bernardo González-Aréchiga and J. C. Ramírez, Mexico City, El Colegio de la Frontera Norte-Fundación Friedrich Ebert.
- , 1991, "El Tratado de Libre Comercio en América del Norte y el medio ambiente de la frontera norte," *Frontera norte* 3 (6):5-28.
- Schoenberger, Erica, 1990, "From Fordism to Flexible Accumulation: Technology, Competitive Strategies and International Location," *Environmental and Planning D: Science and Space* 6:245-262.
- Sedesol (Secretaría de Desarrollo Social), 1990, *Programa Nacional para la Protección del Medio Ambiente 1990-1994*, Mexico City, Sedesol.
- Sedue-EPA (Secretaría de Desarrollo Urbano y Ecología and Environmental Protection Agency), 1992, *Integrated Environmental Plan for the Mexican-U.S. Border Area (First Stage, 1992-1994)*, Washington, DC, Sedue-EPA.
- Taylor, L., 2000, "The Origins of the Maquila Industry in Mexico," paper presented at the International Conference on Free Trade and the Future of the Maquila Industry: Global Production and Local Workers, El Colegio de la Frontera Norte-United Nations Economic Commission on Latin America and the Caribbean, Tijuana, Mexico, October 20-21.

- Tidd, Joe, John Bessant, and Keith Pavitt, 1997, *Managing Innovation: Integrating Technological, Market and Organizational Change*, Chichester, England, John Wiley and Sons.
- Tirole, Jean, 1988, *The Theory of Industrial Organization*. Cambridge, MA, MIT Press.
- U.S. White House, 1998, *National Environmental Technology Strategy*, Washington, DC, The White House. Document accessed at <http://www.whitehouse.gov/NCST> in July 2000.
- Utterback, James M., 1994, *Mastering the Dynamics of Innovations*, Boston, MA, Harvard Business School Press.
- Wise, Timothy A., Hilda Salazar, and Laura Carlsen (eds.), 2003, *Confronting Globalization: Economic Integration and Popular Resistance in Mexico*, Bloomfield, CT, Kumarian Press.

