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COMPETITIVENESS CHARACTERISTICS OF THE ELECTRONICS MAQUILADORA ON MEXICO'S NORTHERN BORDER

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Introduction: The future of electronics manufacturing in Northern Mexico

For at least two decades, the most dynamic part of regional manufacturing on the United States-Mexico border has been the maquiladora industry in Northern Mexico. With growth rates of 10-12% per year up until its peak in October, 2000, maquiladora-based manufacturing has been one of the engines of regional employment and income growth since at least the mid-1980s. More recently, the unprecedented magnitude of the current downturn raises questions about the future of the maquiladora in particular, and manufacturing along the border in general.

Both the national and local media have begun to question the long-run viability of an industry that sprang from a set of tax benefits that seem to be disappearing and that grew on low wage, unskilled, assembly jobs.[1] The entrance of China into the WTO added to a mix that already included the collapse of East Asian currencies during the crisis of 1997-98, a recession in the US industrial sector, and tax uncertainty and confusion brought on by Article 303 of the NAFTA and the Permanent Establishment rules of Mexico's Ministry of Finance.[2]

This paper attempts to address a fundamental question about the long-run viability of the maquiladora industry. It focuses on one of the most dynamic parts of the industry, electronics, in the primary production centers of Tijuana, Mexicali, and Ciudad Juárez. The goal of the paper is to begin to address questions about the long-run viability of manufacturing. Since the future is by definition unknowable, rather than trying to make

[1]For example, *Businessweek,* "The decline of the maquiladora," April 29, 2002, and *The Union Tribune,* "Mexico's maquiladoras rebound, but will it last?," May 31, 2002.

[2] Article 303 of NAFTA changed the rules governing the exceptional tariff status of the maquiladora industry while the Permanent Establishment rule of Mexico's Ministry of Finance changed the tax treatment of income and assets of foreign owned maquiladora firms. Both changes generated uncertainty and confusion in the industry while they simultaneously raised compliance costs.

predictions, we concentrate on the fundamental question of the competitiveness characteristics of the electronics industry. In particular, we ask whether the electronics plants as presently constituted are capable of competing in a head-to-head competition with the world's best.

Our working hypothesis is that internationally competitive firms are more likely to stay in their current locations and to provide more stability to their employees and communities. There is a growing literature in support of this proposition (summarized by Lewis and Richardson, 2001), and it does not seem to violate common sense to argue that globally competitive firms generate more benefits than uncompetitive firms.

We believe we can say something new on this issue as a result of a recently conducted survey of electronics and autoparts maquiladoras in Mexico's northern border region (Encuesta Aprendizaje Tecnológico y Escalamiento Industrial en Plantas Maquiladoras, COLEF, 2002; Proyecto Conacyt no. 36947-s "Aprendizaje Tecnológico y Escalamiento Industrial. Perspectivas para la Formación de Capacidades de Innovación en las Maquiladoras en México", COLEF/FLACSO/UAM; hereinafter referred to as COLEF, 2002). Implemented by researchers at El Colegio de la Frontera Norte (COLEF) in Tijuana, the survey examines technological learning and industrial upgrading in the autoparts and electronics sectors of maquiladora in three northern cities, Tijuana, Mexicali, and Ciudad Juárez.[3] In this paper we approach a fundamental question that is directly related to the issue of competitiveness: Is there industrial upgrading in the electronics sector of Mexico's maquiladora industry? This is a fairly narrow question

[3] Jorge Carrillo Coordinator; COLEF Researchers included Araceli Almaráz, Rocio Barajas, Redi Gomis, Alfredo Hualde and Marta Miker. Funding for the research came from Proyecto Conacyt no. 36947-s "Aprendizaje Tecnológico y Escalamiento Industrial: Perspectivas para la Formación de

which does not address the entire spectrum of competitiveness and survivability issues, but it is a useful first step. We begin with a brief discussion of a framework for analyzing the contribution of foreign direct investment to the international competitiveness of an industry.

The product cycle

Raymond Vernon’s theory of the product cycle (Vernon, 1966) provided one of the first and best explanations for the role of foreign direct investment in the corporate strategies of multinational corporations. Vernon’s work aimed at explaining why capital in high income industrial economies did not flow more quickly to less developed economies, but it also highlighted the relationship between parent companies and their foreign subsidiaries and clarified the role of foreign direct investment in the overall international competitive strategy of multinationals.

Given the importance of foreign direct investment in the northern border states of Baja California and Chihuahua, Vernon's work in especially relevant. Between 1994 and 2001, Baja California and Chihuahua together received over $US 10,000 million in foreign direct investment (FDI), or about 10% of the total received by Mexico during those years. Only the Federal District, with just over 60% of Mexico's FDI, received more. Individually, the two states of Baja California and Chihuahua received roughly similar amounts of FDI and ranked number two (Baja California) and four (Chihuahua) among states. Nuevo Leon received the most FDI of any state (omitting the Federal District) and Estado de Mexico ranked number three, just ahead of Chihuahua (INEGI, 2003). The employment impacts of FDI in Baja California and Chihuahua were

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Capacidades de Innovación en las Maquiladoras en México,” a collaboration between El Colegio de la Frontera Norte, FLACSO-Mexico, and Universidad Autónoma Metropolitana significant, as 46% of Baja California's total employment and 50% of Chihuahua's was in firms with some degree of inward FDI (Secretaría de Economía, 2000). These figures are far higher than those for any other states. Within the sample of electronics sector maquilas in Tijuana, Mexicali, and Ciudad Juárez, 77.9% of the firms have 100% foreign owned capital (U.S., Japan and Korea predominate, but nine other countries have wholly owned plants) (COLEF, 2002).

In the product cycle model, firms use a combination of innovation, market power gained from being the first to enter a particular product market, and transitory barriers to entry, to earn higher than normal profits. The model is particularly useful and descriptive in consumer goods markets, such as consumer electronics, where branding and marketing play important roles in exploiting innovations and enforcing market power.

The stylized facts of the product cycle model are as follows. As an industrialized country innovates a new product, it begins to sell it both at home and abroad, typically in other high income markets. The technological capacity of high income trading partners enables them to copy both products and production processes in a relatively short period. Hence, outward FDI to other high income countries follows. Firms will also begin to look for ways to strengthen their competitive positions internationally, and the need to gain a cost advantage over the emerging competition from high income, technologically sophisticated, countries leads to the outsourcing of component production in developing countries, followed eventually by larger and larger shares of overall production in developing country markets.

In 1966, Vernon argued that firms would need to tightly integrate their global production as part of their overall international competitive strategy, a point that was amply demonstrated by the work of Stopford and Wells in 1972. Integration of the host country's subsidiary into the competitive strategy of the home country's parent firm naturally led to tensions between host country governments and foreign controlled firms. In particular, host country governments feared that so-called "screwdriver plants" would undermine or completely eliminate the benefits of FDI for economic development.[4] It was feared that this would happen as a result of performing skilled and high value added work outside the host country. Consequently, many host country governments put conditions and restrictions on FDI with the intention of ensuring that some of the benefits of FDI spilled over into the local economy. These conditions often limited the ways in which parent company investors could integrate their foreign subsidiaries into an international strategy, and often led to foreign investments becoming "cash cows" which produced for the (often highly protected) local market. These firms helped raise profits for the parent company, but the restrictions on their production processes meant that they were usually not integrated into a global economic strategy.

The dichotomy in foreign owned firms

Foreign owned firms tend to have relatively distinct characteristics that depend significantly on whether they are part of their parent company's international strategy or are simply a means for the parent company to profit from the specific national market where they are located. Moran (2001) identifies several differences between these two types of foreign owned firms. Plants that are integrated into the parent company tend to:

- be wholly owned by the parent company;
- export a large fraction of their total output;
- fully utilize economies of scale in production;
- follow best practices in management, quality control and production technology;

[4] The term stems from the notion that all a host coutnry would have to do is to turn a couple of screws and the plant would be up and running.

- upgrade their management techniques, quality control, and production methods more often;
- provide more human resources training.

All of the above—and their opposites—are visible in the survey of electronics maquila in Mexico's northern border. That is, the electronics maquila contain both elements of the dichotomy emphasized by Moran. Some firms are at the technology frontier, providing high levels of training and following best practices in all the relevant areas of business operations. These firms are an important part of the international strategy of the parent company and are likely to weather short-run and medium-run cyclical fluctuations caused by such factors as a slowdown in US industrial production or an overvalued peso. Other firms in the region lag behind on all of the frontiers, whether in technology, skills and training, or any other indicator of competitiveness.

In order to see this dichotomy more clearly, we turn to the literature on the maquiladora industry and to the recent survey of electronics maquilas in Tijuana, Mexicali, and Ciudad Juárez. The next section examines a variety of areas that directly relate to the characteristics of highly integrated firms enumerated by Moran.

Industrial upgrading in the maquiladora industry

The electronics industry began with plants that assembled simple parts using processes that are intensive in the use of unskilled labor. Over time, plants that are intensive in the use of technology and skilled labor began to appear (Carrillo and Hualde, 1996; Lara Rivero, 1998; Dutrenit, Garrido, and Valenti, 2001). This "industrial upgrading" in the maquiladora industry, or moving up "the ladder of comparative advantage," has been described as an evolution from first to second to third generation maquiladoras (Carrillo and Hualde, 1996).[5] While these designations are essentially metaphorical, they are a useful taxonomy for representing both change over time and the differences between firms at a given point in time. That is, first generation maquilas coexist with second generation, and they both coexist with third. In the survey results described below, there is substantial evidence for all three types.

First generation plants are simple assembly operations that use relatively unskilled, low wage, labor. Although this type of production requires an industrial labor force (or must generate one), issues of quality control and technological complexity of the products and processes are minimally important.

Since the 1980s many researchers have noted that some maquiladoras were implementing, or had implemented, organizational changes associated with Japanese manufacturing techniques, including work-teams, quality circles, worker "multi-qualification," and others (Mertens and Palomares, 1988; Brown and Dominguez, 1989; Carrillo and Ramirez, 1990; Wilson, 1992; Carrillo, 1993; and Contreras, 2000). Carrillo and Hualde (1996) designated this the second generation of maquiladoras, with the intention of singling out plants with higher degrees of decision making autonomy, more advanced manufacturing technology, including automation or semi-automation, higher levels of participation by engineers and technicians, and a clear emphasis on product quality.

The third generation of plants have characteristics that include an intensive focus on the use of information technology, along with the development of R&D capacity, and advanced manufacturing capabilities (Carrillo and Hualde, 1996). Data on the number

[5] Gereffi and Tam (1998) discuss "industrial upgrading" from the disciplinary perspective of the sociology of labor. Bhagwati (2002) describes the "ladder of comparative advantage" from the perspective of trade

and relative importance of third generation maquiladora plants are unsystematic and none of the researchers that have studied the emergence of third generation plants makes a claim that this is an inevitable evolution for all plants.[6] Rather, the case is made that some plants are evolving advanced production processes and are able to produce complex products which are at the industry frontier.

Television production illustrates this evolution. It has evolved from making wooden cabinets (labor intensive, simple commodities) to flat panels, and digital and high definition television sets (Lara Rivero, 1998; Barajas Escamilla, 2000; and Carrillo, 2001a.) A number of plants, for example Sony, Samsung, RCA, and Philips, have their own R&D, particularly in product design, and they manufacture under their own labels and those of other companies. As is obvious when comparing wooden cabinets to flat panels, the level of technology embodied in the products has risen substantially. Even within some standardized products, however, such as wiring harnesses for autos, embodied technology and the rate of technological change is very high (Carrillo and Hinojosa, 2000).

Additional evidence of technological evolution and industrial upgrading in the maquiladora industry is provided by the development of greater decision making autonomy at the local level. Purchases of equipment, selection of suppliers, changes (improvements) in manufacturing processes, selection of manufacturing technology, product design, and other decisions have become more common (Carrillo, Mortimore and Alonso, 1999; Buitelar, Padilla, and Urrutia, 1999; Katz and Stumpo, 2001). The development of greater local autonomy has gone hand-in-glove with increases in quality

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economics. Bhagwati attributes the term to the late economist Bela Belassa.

standards and the use of more skilled labor. Engineers, in particular, have come to play a greater role in maquiladoras (Colef, 2001; Hualde, 2001).

While the primary emphasis of the discussion so far has been on technological changes, organizational changes are also important and a number of studies demonstrate the transfer of new management models. In particular, Taddei (1992) and Kenney and Florida (1994) describe the application of "Japanese production systems" in Japanese maquilas since the mid-1980s. Lara Rivero (1998) and Contreras (2000) show that many Japanese firms have successfully implemented "flexible organizations" and "learning organizations." In Lara Rivero, the case is made that many Japanese firms have introduced the concept of "continuous learning" through individual worker responsibility for quality control, quality circles, and learning through mistakes. Contreras compares electronics firms in Japan with Japanese owned maquilas and concludes that the latter are effectively organized around the concept of continuous improvement (*kaizen*).

Characteristics of the electronics sectors in Tijuana, Mexicali, and Ciudad Juárez

The electronics sector is one of the largest and most dynamic manufacturing sectors in the northern border region. The COLEF survey (COLEF, 2002) was administered to 217 electronics maquiladora plants in the three cities. The definition of the electronics sector is relatively general, but the vast majority of the plants are classified in branches (ramas) 3823, 3831, 3832 of the Mexican economic classification system, Clasificación Mexicana de Actividades y Productos (CMAP). Respectively, these are (1) manufacture and assembly of office, calculating, and information processing machinery, (2) manufacture and assembly of electronic machinery, equipment, and

[6] This is one of the research gaps that the COLEF survey "Aprendizaje Tecnológico y Escalamiento Industrial" attempts to fill.

accessories, including for the generation of electrical energy, and (3) manufacture and assembly of electronic audio-visual, communications, and medical equipment (INEGI, 1999). In 1998, the most recent economic census in Mexico counted 414 firms in the three electronics sectors and three cities, with almost half (193) in the audio-visual, communications and medical equipment manufacturing sector (branch 3832). Taken together, these three sectors employed 222,833 workers in the three cities in 1998, or about 19% of total state employment enumerated by the economic census in the states of Baja California and Chihuahua. Additional descriptive statistics for the sample of plants are contained in the appendix.

Ownership, exports and scale economies

As discussed above, plants that are integrated into the parent company's international economic strategy tend to have a variety of characteristics such as 100% parent company ownership, a large share of output that is exported, and full use of economies of scale in production. Of the 217 firms surveyed, 193 (89%) are 100% owned by their parent company (169 of 217 if the Mexican owned firms are excluded; see Appendix). The advantage of 100% ownership is that it gives the parent company greater protection of its innovations and other elements of its business strategy.

A second characteristic of dynamic foreign-owned firms is that they tend to export more, while foreign-owned firms that are not part of a global strategy tend to produce for the (often highly protected) local market. Of the firms in the sample, 152 firms (73.4% of the 207 valid respondents) export 100% of their product while only 14 firms (6.8%) export 0%. This is perhaps mainly due to the history of the maquiladora industry and its requirement that output be exported. However, the requirement is no longer in place, and regardless of the ultimate reasons for such a high proportion of exports, it is consistent with the profile of internationally competitive firms.

A third characteristic of firms is that they take full advantage of economies of scale. On the other hand, firms that produce for a local market tend to be smaller than average. This often raises production costs since the minimum efficient size for many lines of production is greater than the demand in the local market can sustain. In the Tijuana-Mexicali-Ciudad Juárez sample, the median average sized firm is 290 workers. The largest 43 plants (20% of the sample) have 800 or more workers, and the largest 22 plants (10% of the sample) have 1,370 or more.

In order to provide some perspective on economies of scale, Table 1 compares US, Baja California, and state of Chihuahua plant sizes in the electronic equipment sector. These are mean averages (workers divided by plants) rather than median averages, and they cover all plants in the two states, not just maquilas. Comparison of similar sectors indicate that the firms in Mexico tend to be much larger than those in the United States.

Table 1: Evidence on scale economies in electronics*

	Workers per plant
Baja California (1998)**	313
Chihuahua (1998)**	759
US (1997)	94

*CMAP branches 3823, 3831, 3832 in Mexico; NAICS codes 334, 335 in the US. **Baja California data are for all firms, both maquila and non-maquila. Sources: INEGI, 1999a and 1999b; US Census Bureau, 2001.

Product differences between the US and Mexico make a direct comparison relatively weak, but it does indicate that there is no simple evidence pointing to a lack of economies of scale. Indeed, given its export orientation toward a world market, the scale of operations in profitable plants requires a minimum efficient size.

Best practices and industrial upgrading

Management practices, quality control, and production technology all stand out in the survey. What is remarkable is the heterogeneity of the industry. Survey questions directed towards uncovering information about the level and rate of change of industrial technology and management practices, portray a maquiladora sector with a wide range of practices.

Table 2 illustrates this point. Firms were asked to rank their technology compared to the world level. As shown, more than one-third thought they were comparable to the best, but over one-fifth were 5 to 10 years behind.

Table 2: Technology compared to the world level

Level	*Percent of firms*
Comparable to the best	42.9
1-2 years behind	15.3
5-10 years behind	21.0

Source: COLEF (2002) Section 3-2.

Plants at the technology frontier have capabilities that go beyond assembly and manufacturing. Table 3 contains survey results showing that over one-fourth of the surveyed plants engage in research and development (R&D), one-fifth do product design, and over one-tenth of the plants have developed a patent. For the minority of firms with these characteristics, and perhaps for many others as well, international competitiveness is a matter of the application of technology and skill.

Table 3: Indicators of industrial upgrading

Activity	*Plants actively engaged, in percents*
Research and development	20.9
Product design	16.7
Product testing	80.6
Developed a patent	10.2

Source: COLEF (2002) Sections 2-4 and 3-13.

ISO certifications are another indicator of the use of best practices. The International Organization of Standards (ISO) is a network of national standards institutes that claims participation by over 140 countries (http://www.iso.ch/). Initially, it limited its standards-setting activities to highly specific technical standards, mostly of use to engineers, but in 1987 it began a program to certify generic management system practices (ISO 9000), aimed at ensuring that businesses are capable of delivering the product or service that its customers require. The ISO 9000 series was followed in 1997 by the ISO 14000 series of environmental standards, aimed at ensuring that a plant's production processes minimize the harmful effects they have on the environment. Table 4 shows the share of plants attaining different kinds of ISO certification.

Table 4: ISO Certifications

ISO Certification	*Number certified (%)*	*Number in process*	*Number certified in last 3 years*
Management systems			
9000	21 (9.7)	6	9
9001	50 (23.1)	8	23
9002	85 (39.4)	10	30
Environmental controls			
14001	29 (13.4)	4	19
14002	3 (1.4)	2	2

Source: COLEF (2002) Section 3-12.

Given that the ISO 14000 certifications are newer (created in 1997), fewer plants have obtained them. Note that ISO 9001 are relevant to plants that do R&D, and the percentage of plants claiming to have ISO 9001 is nearly the same as plants that claim to do R&D.

Tables 2, 3, and 4 indicate that perhaps one-fourth of the maquiladora in the electronics industry could be considered third generation. This group is joined by another 10-15% of plants that do not do R&D or product design, but that are at the technology and management frontiers of their industry. In sum, between 20 and 30% of the plants sampled are "comparable to the best.".

According to the numbers cited in Table 2, an additional 10-20 percent of the plants is not far behind. Table 5 shows that a relatively large share of plants is actively upgrading technology, management skills, and product quality. Nearly Sixty-three percent of plants increased their level of engineering input over the last three years, 67.6% increased their management skill levels, and nearly 80% of the respondents said that the quality of their product improved.

Table 5: Indicators of competitiveness

	Changes over the last 3 years	
Activity/area	*Increased (%)*	*Decreased (%)*
Market share	49.1	27.6
Number of customers	41.9	27.0
Complexity of production	48.1	12.6
Automation	45.5	4.2
Quality of product	79.5	0.5
Level of engineering input	62.6	2.3
Management skill level	67.6	3.8
Rejects for quality reasons	5.2*	94.8

*Rejects based on quality increased or stayed the same.
COLEF (2002) Sections 2-8 and 4-5.

Tables 6 and 7 are similar to Table 5, but focus on technology. Whereas in Table 5, a total of 48.1% of the respondents said the complexity of production increased during the last three years, in Table 6, a total of 39.9% said technological innovation in production processes were relatively frequent. One might infer from Tables 6 and 7 that the upgrading of production processes is connected to the upgrading of information systems, an area where many firms have been active investors (Table 7).

Table 6: How common is technological innovation?

	Innovation in the last 3 years	
Activity/area	*Frequently (%)*	*Never (%)*
Equipment	29	38
Processes	50	20
Products	30	38
Information systems	45	17

Source: COLEF (2002) Section 4-2.

Table 7: Information technology investments in last 3 years

Important investments in last 3 years	*Firms*
Computational resources	82.4%
Median number of computers per plant	35
Plants with internet connectivity	98.2%
Software	89.9%
Cables, telecommunications, etc.	79.2%

Source: COLEF (2002) Sections 5-1, 5-2, and 5-5.

Human resources

According to Moran (2001) and others, subsidiaries that are integrated into the international competitive strategy of their parent company provide more training and upgrading of human resources than plants that are not similarly integrated. This follows from their need to stay abreast of current trends and developments. Tables 8 and 9 shed some light on the relative importance of skills and training in the local electronics and autoparts maquila.

Table 8: Skills, training, and education

	Firms with changes in last three years, in percents		
	Increases	No change	Decreases
Number of engineers	34.6	38.5	26.9
Number of professionals	38.3	37.9	23.8
Education level of workers	44.2	54.0	1.9
Skills	58.5	35.8	5.7
Hours of training	45.3	37.3	17.5

Source: COLEF (2002) Section 7-10.

Table 8 shows that one-third of the firms sampled experienced increases in the number of engineers, and a slightly higher 38 saw an increase in the number of professionals. Again, this is roughly the same percentage as firms that consider their technology comparable to the best (42.9% in Table 2), or that have obtained ISO 9002 certification (39.4%, Table 4), and quite a bit more than the percent doing R&D (20.9%, Table 3).

Table 8 also sheds light on the lagging firms. Nearly 54% of the firms have not increased their hours of training, while 62% have held constant or declined in the number of professionals, and nearly two-thirds have a similar pattern for the number of engineers. This is consistent with Table 6, which shows that about 30% of the plants have not innovated equipment or products over the last 3 years (Table 6) and 42% are more than 2 years behind the technology frontier (Table 2).

Table 9: On-the-job learning for engineers and technicians

Primary method	*Percent of plants*
Formal work groups	17.1
At the parent company	12.4
Individual practice	29.5
On-site training offered by the parent company	13.8
Courses at local institutions	21.0
Informal work groups	5.7

Source: COLEF (2002) Section 8-5.

When foreign subsidiaries of multinationals are integrated into the global strategy of the company, more human resource training occurs. One of the indicators of this fact is that a share of the training takes place via rotations through the parent company's home branches or offices. Table 9 shows a variety of mechanisms through which training of engineers and technicians occurs, including about 26% of the plants that use training at the parent company or on-site training provided by the parent company as their primary means. About 21% of the firms depend on courses at local institutions, indicating that there are active links to nearby private and public training facilities.

First, second, and third generation maquilas

Technological sophistication does not guarantee a competitive firm. Indeed, the promise of competitive success cannot be guaranteed under any circumstances. Still, firms that are at the frontier of their industry and that compete successfully in an international arena where national policies offer little in the way of protection, are more likely to succeed in the long run. In part, the discussion of 1^{st}, 2^{nd}, and 3^{rd} generation maquiladora plants is related to the widespread desire to understand the competitive future of the industry. Third generation plants are at a competitive advantage relative to 2^{nd} and especially 1^{st} generation plants, because they can innovate products and processes, apply best-practices management techniques, and compete on the basis of product quality.

The relative importance of 1^{st}, 2^{nd}, and 3^{rd} generation plants is uncertain, in part because the categories themselves are not precisely definable. Based on the data presented, however, a rough accounting for the size of each group can be estimated, at least for the combined electronics autoparts sectors of Tijuana, Mexicali, and Ciudad Juárez. Depending on the indicator, somewhere between 25% and 35% of plants seem to be at the technology frontier. This 25-35% accords with the number claiming to be at the frontier of their product category (42.9%), have ISO certifications (39.4% have 9002), upgrade their equipment (32.4%) and products (28.3%) frequently, and have increases in the number of engineers (34.6%) and professionals (38.3%).

At the other end, it appears that around 40% of the sample consistently lags. This is roughly the size of the group that is three or more years behind in technology (42%), that has neither ISO 9001 nor 9002 certification (38%), that never innovates in equipment (27.2%) and products (30.7%), and that has held constant or decreased the number of engineers (65%), professionals (62%) and hours of training (55%) in its plants. These plants are more likely to compete primarily on the basis of prices, rather than product quality or some other feature, and to look for locations with abundant supplies of low-wage, unskilled, labor. The information in Table 10 is consistent with this view. Forty-two percent of the sample stated that they competed primarily on the basis of price.

Table 10: Primary source of competitiveness

Source	*Percent of firms*
Quality	38.4
Price	42.1
Delivery time	9.7
Economies of scale	2.8

Source: COLEF (2002) Section 2-10.

What explains the recent downturn?

The primary purpose of this paper is to characterize technological learning and industrial upgrading in the electronics and autoparts sectors of Tijuana and Mexicali's maquiladora industry. We would be remiss, however, if we did not briefly address the recent decline in the numbers of firms, workers, and production.

In order to account for the layoffs and plant closures over the last 1.5 years, the slowdown in US industrial production has to be taken into consideration. Activity levels in the maquiladora industry are, in part, determined by level of industrial activity in the US (Gerber and Balsdon, 2001; Gruben, 2001; Fenandez and Navarette, 1986). Gerber (2002) provides a relatively succinct analysis based on parameter estimates taken from econometric models developed by Gerber and Balsdon (2001) and Gruben (2001). These two papers employ different models and different statistical techniques to arrive at very similar conclusions. Namely, a 1% decline in US industrial production leads to a decline of just over 1.25% in maquiladora employment nation-wide. The effect, then, of the slowdown in US industrial production is a 8-9% loss of jobs in the maquiladora industry, or about 40% of the actual job loss (20% of total employment was lost from October, 2000 to April, 2002.)

A second key factor in the current situation is the relative strength of the peso. While the peso has begun to fall very recently, over the last several years, it has increased about 20% in value against the US dollar, and about 30% against East Asian currencies. Given the parameters found in Gruben (2001), the rising dollar cost of Mexican labor may explain another 25-30% of the employment loss.

Taken together with the slowdown in US industrial production, between 65 and 70% of the job loss is easily explainable. Support for this notion comes from the recent turn around in US activity and the very recent decline in the peso. While both factors tend to effect the maquiladora industry with a lag,[7] employment figures for 2002 show a flattening out in the rate of job loss, and an actual increase in April, 2002.

This still leaves around one-third of the job losses unexplained, for which there are a host of possibilities: China's entry into the WTO, confusion over the new tax rules, both in the area of Article 303 and its replacement (Programa Sectoral) and in the now resolved area of Permanent Establishment, safe harbor, and advance pricing agreements

[7] The lag for the impact of the US slwodown is around seven months; for changes in the value of the peso it is somewhat longer, perhaps 1-2 years. Note, however that US industrial production began to rise last October, and that maquiladora employment followed in April—seven months later.

(Gerber, 2001), problems of security, and lack of infrastructure such as the water shortages in Tijuana and the growing energy shortage throughout northern Mexico.

The link between layoffs in the industry and the discussion of 1st, 2nd, and 3rd generation maquiladora should be obvious. Few firms, regardless of their technological or managerial sophistication can be considered free from the effects of business cycles and currency values. Second and third generation firms, however, represent long-term commitments to the region with greater investments in technology, industrial upgrading, and managerial skills. There can never be a guarantee that these plants will not leave the region,[8] but they at least have tools that will allow them to cope with the adverse impacts of external economic events.

Conclusion: Manufacturing in the long run

Based on the analysis offered in this paper, electronics manufacturing has a solid foundation for a long run presence in the region. Growth will not be constant, however, and a long run decline is not totally inconceivable. From a probabilistic perspective and in the long run, expansion seems more likely than decline. The solid foundation of technological upgrading, internationally competitive firms, best practice management skills, constant innovation, and competition on the basis of product quality, make a strong case for production staying in the region in the long run.

This is not to say that plants will not shut down. Approximately 40% of the electronics and autoparts sectors appears very vulnerable to world trends in prices and labor costs. These 1st generation plants may have an advantage to location in Tijuana or Mexicali given that they are part of a larger industrial cluster which has created an industrial labor force and service suppliers, but they are also much more likely to be influenced by rising labor costs since they compete primarily on the basis of the price of their product and to a lesser degree on product quality or timely delivery.

Two key issues have not been addressed in this paper. One is the extent to which the electronics clusters is representative of overall manufacturing, and another is the problem of linkages to the rest of the economy. These issues are not unrelated if we look at them from the perspective of a cross-border economy. One of the criticisms of the electronics industry is that it is not well-linked to either the local Mexican economy or to U.S. border or near-border cities with significant R&D, such as San Diego, Los Angeles, Austin, and so forth. In the case of San Diego, this lack of cross-border integration in electronics is probably mostly the result of the relative unimportance of manufacturing on the north side of the border, and the lack of a consumer electronics sector in particular. In addition, San Diego's R&D strengths do not match production in Tijuana, located as they are in wireless communication, digital media, and biotechnology.

Still, the future may hold some hope of cross-border industrial integration in ways that serve both sides. In particular, the growing maquiladora sector of medical devices and equipment is geographically well-positioned to take advantage of an area of strength in San Diego. The San Diego Association of Governments (1998) identified this sector as a regional (San Diego) cluster, employing more than 6,000 workers north of the border in 1996, and feeding off the R&D and high technology capacity of local firms, universities, and hospitals.

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[8] In a panel of US firms, Davis, Haltiwanger, and Schuh (1996) found that approximately 10% of all manufacturing jobs were destroyed each year in the US, with an approximately equal number created. The rule is that manufacturing is highly innovative and in a constant state of change.

And finally, the issue of linkages to the local Mexican economy has not been addressed. The COLEF survey sheds light on this issue, but it is a separate topic with too many elements to be addressed in this paper. A couple of points are worth mentioning, however. One is that a number of linkages have been created to local service suppliers, such as transport (cargo and people), maintenance firms, finance (on the San Diego side of the border), food service, and others. In addition, it is possible that there is an undercount of parts and components suppliers due to the mis-counting of trade between maquilas. Even if the linkages are weak, however, the other benefits of foreign direct investment, namely technology transfer and skill creation, seem strong.

Appendix
Characteristics of the Tijuana/Mexicali sample

217 firms*
- 110 in Tijuana;
- 42 in Mexicali;
- 65 in Ciudad Juárez.

Ownership:
- 104 firms 100% US owned;
- 26 firms 100% Japanese owned;
- 17 firms 100% Korean owned;
- 22 firms 100% owned by other, non-Mexicans;
- 24 firms 100% Mexican owned;

Exports:
- 152 firms (73.4% of valid respondents) export 100% of their product;
- 14 firms (6.8%) export 0% of their output;
- 26 firms (13.5%) export less than 50% of their output.

Size:
- 60 or fewer workers: smallest 20% of plants;
- 173 or fewer workers: smallest 40% of plants;
- 290 workers: median;
- 800 or more workers: largest 20% of plants;
- 1370 or more workers: largest 10% of plants.

Distribution of workforce by occupation:
- Production workers, median share: 80%;
- Technicians, median share: 10%;
- Administrators, median share: 9%;
- Directors and managers, median share: 2%.
- Average number of engineers per plant: 6.

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