Industrial Concentration in Assembly Production: The Case of the Maquiladora Sector in Mexico

by

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Abstract

The number of offshore assembly plants in Mexico—locally called *maquiladora* plants—has increased dramatically during the past decade. Today, the maquiladora sector employs more than 460,000 workers and has become the second most important source of foreign exchange for the country. Several authors, however, have questioned the sector's ability to serve as a springboard for long-term economic development. Maquiladoras have remained, for the most part, low-wage enclave operations that have established few linkages to the communities where they locate, and are, therefore, largely footloose. Moreover, as changes in the dynamics of global industry develop, the viability of sustained economic growth based on assembly production seems ever more uncertain. Will automation and new management techniques translate into a reconcentration of production in the developed countries? How are the maquiladoras adapting to those changes? Is it possible to spur economic growth based on assembly production?

In order to contribute in answering the above questions, in this thesis, I explore the spatial profile of maquiladora production. In particular, I try to identify clusters of maquiladora industries where *localization economies* exist. Rather than locating in a city only because low-wage labor is available, the existence of local suppliers and/or specialized labor skills becomes an important location factor as well. Thus, localization economies offset the maquiladoras' footloose character. Through the use of econometric and statistical techniques, I conclude that there is indeed evidence of localization economies in some maquiladora industries. Nonetheless, my results are not conclusive, and future researchers must look at detailed case-study data about the way in which maquiladoras interact with their host communities. Thus, I conclude by presenting an agenda for future research.

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Chapter 1

Introduction

Offshore assembly production in Mexico—locally called *maquiladora* production—has increased in importance at an astonishing rate during the last ten years.[1] Maquiladoras have been a source of employment and foreign currency for Mexico at a time of financial and economic duress. Today, maquiladoras employ more than 460,000 workers—nearly twice as many as in 1986.

Aside from their positive impact on employment creation, analysts criticize assembly plants on issues ranging from environmental degradation to their excessive reliance on unskilled young women workers. In particular, maquiladoras have shown little integration into the Mexican economy. Maquiladoras have established few *backward* and *forward linkages* to domestic industries, i.e., they acquire a very small percentage of its inputs from Mexican suppliers and do not sell their output in Mexico; other types of linkages—technology transfer, skill upgrading—have also been minuscule. As such, researchers view the maquiladoras—and, for the most part, rightly so—as mere enclave operations that locate in Mexico to take advantage of low labor costs and physical proximity to the United States.

The unintegrated character of the maquiladora sector calls into question the maquiladora's viability as a long-term development strategy. First, the lack of

[1]Henceforth, the word *maquiladora* will be used in various ways: *maquiladoras* and *maquiladora plants* refer to assembly plants; *maquiladora sector* refers to all plants in the assembly sector; *maquiladora industries* are all of the industries comprised by the maquiladora sectors (see Appendix A for a listing of all the maquiladora industries).

linkages to the economies of those communities where maquiladoras locate has favored a view of assembly production as a largely footloose sector. Second, the conditions that gave rise and dynamism to maquiladora production may be changing. Automation and new forms of industrial organization may lead to a spatial relocation of production from low-cost developing countries to the old industrial cores of the developed world. Accordingly, the comparative advantage of maquiladora communities, namely, low wages, may become irrelevant to the needs of global capital. Given that some communities depend heavily on maquiladora employment, the footloose nature of the maquiladora sector is worrisome, as those communities may be prone to mass unemployment and economic distress.

The above factors and events call for a better understanding of the way in which maquiladoras relate to their host communities and of the overall spatial profile of assembly production in Mexico. Such understanding is essential for assessing the potential to spur economic growth based on maquiladora activities and for minimizing the social costs related to them. In this thesis, we attempt to contribute to the study of the maquiladora sector by identifying clusters of maquiladoras where *localization economies* exist. Rather than locating in a city only because low-wage labor is available, the existence of local suppliers and/or specialized labor skills becomes an important location factor as well. As a result, localization economies are important in offsetting the footloose character of assembly production.

1.1 Background

In 1964, the Mexican government introduced the Border Industrialization Program (BIP). Following the experience of some Asian nations, the Mexican government perceived the development of an export-processing zone located in a 20-mile band along the Northern border as an effective strategy to promote industrialization in border localities. This strategy guaranteed no interference with import-substitution industrialization, which the government strongly encouraged at the time

(Grunwald,1990/91; Wilson, 1989).[2] In addition, the BIP also attempted to prevent widespread unemployment in border localities after the unilateral termination of the 'Bracero Program' (officially, the Mexican Labor Program) by the U.S. government in 1964 (Fernández-Kelly, 1987, 150).[3]

In addition to U.S. tariff-items 806.30 and 807.00[4] the BIP fostered an explosion in assembly production along the Mexican border. In 1970, there were 120 maquiladoras in the country, all of them located in border municipalities, employing over 20,000 workers (Martínez, 1978, p. 133); by 1975, the number of maquiladoras had reached 454 and employed more than 67,000 workers (Fernández, 1989, p. 94). Today, there are approximately 1900 maquiladora plants employing over 460,000 Mexican workers. The maquiladora sector has become, after the oil industry, the second most important source of foreign exchange for Mexico; in 1988, it provided $2.2 billion in foreign exchange earnings to Mexico (Biedermann, 1989, p. 539). The expansion of maquiladora activities is not only notorious in absolute terms: relative to other developing countries, in 1985, Mexico accounted for 40% of the value of all exports to the United States under tariff items 806.30 and 807.00 (Fernández, 1989, p. 94). Interestingly, in 1983, the state of Chihuahua's 806.30 and 807.00 exports to the United States surpassed those of Mexico's major competitors (Singapore, Taiwan, Malaysia, and Hong Kong)[5] (Haring, 1985, p. 68).

Thus, over the last 25 years, Mexico has experienced an impressive increase in export assembly manufacturing. Nevertheless, maquiladoras have been criticized on several grounds. First, analysts have pointed to the maquiladoras' minimal linkages to local firms or to domestic Mexican industry in general. The relative weight of Mexican non-labor material inputs on value added in Mexico has remained

[2]Presently, maquiladora activities are allowed anywhere in Mexico.

[3]The Bracero Program allowed Mexican nationals to work in the United States' agricultural sector since 1942. At the end of the program an approximate 200,000 workers faced abrupt repatriation to Mexico. For a detailed overview of the Border Industrialization Program see Fernández-Kelly (1983).

[4]Tariff-items 806.30 and 807.00 are the legal statutes that allow maquiladora inputs into the United States. They allow for the importation of goods assembled from U.S. inputs, with a duty paid only on value added in the assembling country.

[5]These figures, however, understate that, while virtually all of Mexico's maquiladora production is exported to the United States, Asian producers also export to Japan and Europe.

at a very low level. In June 1991, Mexican material inputs represented only 5.5% of value added, in spite of increases over the last few years. Furthermore, the ratio of Mexican to total material inputs has remained at around 2.0%. This ratio is even lower in border localities, where proximity to the United States and low transport costs bring it down to 1.0%, compared to 2.3% in hinterland locations.

Second, observers have criticized the maquiladoras for their heavy reliance on women workers. In a study of the maquiladora labor force in Juárez, Fernández-Kelly found that women working in maquiladora plants are usually the main source of income to their families. However, "the involvement of women in paid industrial labor . . . does not necessarily represent [an] improvement of their alternatives as individuals and as members of families." (Fernández-Kelly, 1983, p. 192) Several studies argue that working women are subject to sexual harassment and that they are liable to dismissal upon becoming pregnant (The Development GAP, 1991). In addition, according to The Development GAP[6], a study in Nogales, Sonora, maquiladora workers' babies were three times more likely to have a low birthweight than non-maquiladora workers' babies. (The Development GAP, 1991, p. 7)

Third, critics have also accused the maquiladoras of environmental degradation. "Maquiladora plants are notorious for disregarding environmental regulations." (The Development GAP, 1991, p. 5) Even though Mexican environmental laws are stringent, enforcement is poor due to budget limitations. For instance, Kochan (1989, p. 3) reports that, in the state of Chihuahua, SEDUE[7] has at most two inspectors to enforce environmental regulations regarding the disposal and transportation of maquiladora wastes. Estimates indicate that Juárez maquiladoras alone generated 5,000 tons of waste a year; nevertheless, the city "has no sewage treatment system and no nearby state-of-the-art hazardous waste disposal facilities."(Kochan, 1989, p. 12) Mexican law requires that maquiladoras ship their raw chemical wastes back to the United States following production in

[6]The Development Group For Alternative Policies, Inc.
[7]Mexico's Secretariat of Urban Development and the Environment.

Mexico (Warner, 1991, p. 244). However, ineffective tracking of materials crossing the border (in either direction) and lax enforcement in Mexico raise the possibility that wastes are illegally being disposed of in Mexico. Furthermore, in the case of solvents, companies have found ways to circumvent the requirement of returning them to the United States. Solvents can be shipped temporarily to the United States and sold there to a Mexican recycling firm; the Mexican firm brings the solvent back into Mexico, where it is recycled at a low cost; the recycled solvent is then re-exported to the United States, and the resulting wastes become "Mexican property." Inspectors found that one such recycling facility in Chihuahua lacked appropriate safety training and equipment and caused solvent spills outside its facilities. (Kochan, 1989, p. 5).

Finally, researchers have pointed out that maquiladoras place a heavy burden on the infrastructure of those communities where they locate. Insufficient infrastructure not only affects the populations of those cities; it has also proved detrimental to the maquiladora industry itself. Financial limitations make it hard for local governments to enhance infrastructure and to keep pace with maquiladora growth. A study by George (1991) of Juárez and Chihuahua showed that infrastructure in these cities is rapidly deteriorating. New immigrants find it increasingly hard to obtain decent housing and basic services. "[T]here are investment incentives that exempt these businesses from taxes that might fund programs of housing, water, education or other necessary community projects." (The Development GAP, 1991, p. 7) While some maquiladora associations have tried to support infrastructure provision through ad hoc, voluntary contributions to local governments, propositions for small tax treatment of maquiladoras have encountered strong opposition (George, 1991, p. 230).

Thus, maquiladoras have created both opportunities and problems to those communities where they locate. Job creation has been paralleled by diseconomies of scale: as the size of the maquiladora industry increases, social, environmental, and financial costs have arisen. Nonetheless, the conditions that gave rise and dynamism to maquiladora production may be changing. Automation and new forms of industrial organization may lead to a relocation of production from low cost developing countries to the old industrial cores of the developed world in the near future. Under this scenario, those communities and regions that rely heavily on offshore production would be prone to mass unemployment and economic distress. These events call for a better understanding of the way in which maquiladoras relate to their host communities and to the overall spatial profile of assembly production in Mexico. Such an understanding is essential for identifying the potential to spur economic growth based on maquiladora activities and for minimizing the social costs related to them.

1.2 Research description

We have argued thus far that an understanding of the spatial profile of assembly production is needed. Accordingly, we intend to study the geographical characteristics of maquiladora production in Mexico. In particular, we try to identify industrial clusters of maquiladora plants in Mexican cities, that is, above-average concentrations of maquiladora industries at a particular location. At the same time, we show the importance of industrial concentration and explore the nature of clusters by looking for external economies of localization.

Hypothesis

In this thesis we test the hypothesis that industrial concentration results from the existence of *localization economies* in some industries. Localization economies imply that any and all firms in an industry *benefit* as the size of the industry in a particular location increases. Such benefits manifest themselves as a decrease in average costs. Three factors have been identified as causing localization:

1. Firms benefit from a larger pool of workers with the skills needed by the industry.
2. Firms benefit because a larger industry fosters the creation of more efficient and inexpensive suppliers at the local level.

3. Localization favors the flow of information among firms and facilitates a rapid internalization of technological improvements and adaptation to market changes.

Alternatively, we can explain industrial concentration by the existence of *urbanization* economies. Urbanization economies arise due to a greater availability of diverse and specific services in larger cities. Similar to the effect of localization economies, urbanization economies bring production costs down in the industry; the reduction in costs, however, is independent from the size of the industry.

Significance

It is important to identify industrial clusters for three reasons. First, identifying clusters helps pinpoint areas where external economies of agglomeration exist. External economies result from economies of localization or urbanization, or a combination of the two. Localization economies are important because, rather than locating in a city simply because a large supply of inexpensive labor exists, firms settle at a location because of the existence of local suppliers and/or specific labor-skill characteristics. As a result, localization economies offset the footloose character of maquiladoras.

Second, identifying clusters could also help local governments orient their efforts to promote local development. Instead of fostering an increase in the overall level of maquiladora employment or in the total number of firms in their communities, local governments may find it more efficient to target incentives to those firms that present a larger development potential—that is, firms in industries that purchase a larger fraction of domestic inputs and that can transfer technology and skills to the local economy. Of course, such targeting of incentives requires a more careful look at the existing links between domestic and foreign-owned firms, or at the interaction between the local labor force and maquiladoras. Identifying industrial clusters and localization economies points to industries that could potentially receive incentives.

Third, knowledge of the existence of industrial concentration helps analysts structure a more systematic evaluation of the maquiladora's ability, or lack thereof, to adapt to the technological and organizational changes in production that are taking place in the global economy. Several authors (Hoffman and Kaplinsky, 1988; Sanderson, 1987; Womack 1987) argue that spatial concentration and increased cooperation among firms improves the firms' competitive edge. By focusing on clustered industries, we can undertake an evaluation of interfirm cooperation arrangements and transactional networks among maquiladoras.

As stated above, in this thesis, we look at the existence of industrial clusters and test for the presence of localization economies. It is not within the scope of this thesis, nor is it possible for me at this moment, to provide a deeper understanding of why maquiladoras may concentrate in space, that is, which characteristics in each industry and city favor localization. To shed light on the factors that may foster an industry's concentration in a given locality, future analysts would need detailed case studies and enhanced data. We conclude, therefore, by presenting an agenda for further research.

Methodology

We look at the five largest industries in the maquiladora sector, namely: (i) *electric and electronic components*; (ii) *electric and electronic goods*; (iii) *transportation equipment*; (iv) *textiles*; and (v) *furniture assembly*. We also analyze other industries in some cases, but, since they are not well represented in all cities, we were unable to undertake significant statistical and econometric analysis. In addition, we use data on the maquiladora sector for 17 Mexican metropolitan areas. The cities analyzed are the largest maquiladora production centers in the country and account for 84% of all maquiladora employment and 63% of all plants. We obtained the data under a special agreement with the *Instituto Nacional de Estadística, Geografía e Informática* (INEGI) of Mexico. The agreement restricted the use of the data for the purposes of this thesis, requiring that no information be made available that would help identify any individual firm.

We applied several techniques to study the spatial characteristics of assembly production and to identify industrial concentration; they include (i) the location quotient, (ii) the specialization coefficient, (iii) the localization coefficient, and (iv) shift-share analysis. In order to gather evidence for or against localization or urbanization economies, we computed rank-correlation coefficients between industrial concentration and city and industry characteristics. We then compared rank-correlation results to results from a structural econometric model.

Findings

There is some evidence for localization economies in three industries: (*textiles, transportation equipment,* and *electric and electronic components*). In contrast, localization factors were negligible in the *furniture industry* and the data were inconclusive with regard to *electric and electronics goods* maquiladoras. Nevertheless, our results are not conclusive. Therefore, future researchers must confront the results of this thesis against detailed case-study information in order to determine what agglomeration factors, if any, might be at play.

1.3 Thesis outline

The thesis is organized as follows. In Chapter 2, we review the literature on offshore assembly production and then proceed to sketch a theoretical framework for analysis. In Chapter 3, we present the techniques used to analyze the spatial profile of assembly production; we also present figures on the extent to which concentration occurs and relates concentration to characteristics of the locality and of the industry. After that, we apply an econometric model to distinguish between localization and urbanization economies and the model's results (Chapter 4). Finally, in Chapter 5, we present the thesis conclusions and set forth an agenda for future research.

Chapter 2

Literature review

An understanding of the origins, development, and geographic characteristics of the maquiladora sector in Mexico, and of offshore assembly production in general, requires an inquiry into the dynamics of the global industrial system and their spatial manifestation. Nonetheless, because of the international character of assembly production, analyst have paid little attention to the study of the intra-national spatial impact of assembly production. In fact, the location decision of assembly plants takes into account both international and intra-national aspects and consists of several stages. First, a corporation must decide whether to remain producing in its home (industrialized) country or to ship production abroad; that is, it weighs the viability of offshore assembly production *vis-a-vis* production at home. Second, if offshore assembly is selected, the corporation or parent firm must choose a country with appropriate conditions for assembly production—low wages, macro-economic and political stability, a passive or controllable labor force, etc. Third, once the corporation has chosen a country, it must decide where in that country assembly production will take place.

In the current chapter, we present a number of theories that can be used to explain the locational choices of assembly production. The analysis of such choices necessarily involves an examination of the origins of offshore production; hence, we present an outline of the main theoretical currents attempting to explain offshore assembly. Yet, in keeping with the general topic of the thesis, we focus on the experience of the maquiladora sector in Mexico and analyze some theories that may explain locational patterns of the maquiladora *within* Mexico. In particular, we look at the rationale for and significance of industrial concentration.

2.1 The dynamics of assembly production

During the last three decades there has been a change in the type of products exported from the developing countries to the industrialized world. Whereas, in the past, developing nations and former colonies served as a source of raw materials to the developed countries, at present, the export of manufacturing goods has become increasingly important. Starting in the 1960s, a number of transnational corporations moved to the developing world in search of inexpensive labor to assemble simple manufactures for export to high-wage countries. This upsurge in export assembly manufacturing was not restricted to the now so-called *Asian tigers*—Taiwan, Korea, Hong Kong, and Singapore—which have since developed at a rapid pace. It was also present, with not so auspicious results, in other countries as well (e.g., the Dominican Republic, Colombia, Morocco, Indonesia) (Frobel et al., 1980; Wilson, 1989).

The nature of export assembly production has been a subject of much academic debate since the 1960s. The debate has focused on the main determining factors of assembly production. On the one hand, neoclassical economists have emphasized production factor-endowment differentials as the most important justification for offshore assembly production. Life-cycle theorists have added a dynamic dimension to the neoclassical account by looking at how production and factor requirements vary over time. On the other hand, other authors have explained assembly manufacturing in terms of the changes in the structure of the global capitalist system; for the sake of discussion in the thesis, we group the theories of these authors under the label of *structural theories* (Storper, 1981).

2.1.1 The Heckscher-Ohlin model

Early this century, Swedish economists Eli Heckscher and Bertil Ohlin proposed a model to explain international trade patterns. The model, which came to be known as the Heckscher-Ohlin (H-O) model of international trade, has also been used to explain differences in inter-regional industrial production. The Heckscher-Ohlin model assumes that relative factor endowments determine where industrial production takes place and, consequently, where firms and industries locate; for this reason, the H-O model is also known as the *factor proportions model*. Accordingly, a country or region will produce and export products that require the intensive use of the inputs in which the country (region) is richly endowed relative to other regions. For example, a capital-abundant country will export capital-intensive commodities (e.g., cars) and import labor-intensive goods (e.g., clothes) from other countries. Furthermore, the Heckscher-Ohlin model assumes that factor-cost differentials become smaller and eventually disappear as factors of production move to regions where the returns to their use are higher; the same result holds even if factors are immobile but trade is permitted.[1]

The H-O model has been subject to much scrutiny. Among the strongest challenges to its validity is the so-called *Leontief Paradox*. Wassily Leontief (1953; 1956) examined the factor content of U.S. exports. To his surprise, he found that the United States, considered to be a capital-abundant country, seemed to specialize in the export of labor-intensive products. Such findings contradicted the main proposition of the H-O model, namely, that the capital-intensive American economy would specialize in exporting capital-intensive goods. The paradox was explained by Leontief as the result of the higher productivity of American workers (in the post-World War II international economy) than worker productivity elsewhere. Thus, a higher productivity makes labor the relatively abundant factor in the United States. Other authors have argued that American exports are "material capital plus human capital" intensive (Moroney and Walker, 1966, p. 575). Thus, a more skillful

[1]The equalization of factor prices due to trade was first suggested by Paul Samuelson; thus, the H-O model is sometimes known as the Heckscher-Ohlin-Samuelson model.

American labor force exports products that embody a high capital content.[2] In addition to international tests of the H-O model, other authors have tested the application of the model to interregional trade. For instance, Moroney and Walker (1966, p. 584) found that "the H-O hypothesis seems to have some value in predicting regional patterns of industrial development," but as factors move to those regions where their price is higher, initial endowment conditions lose relevance.

The Heckscher-Ohlin model rests on the assumption that the production function for each commodity is the same across countries. In other words, the production of any good requires the same proportion of input usage in any country. However, it is both theoretically and empirically possible to produce the same good using different proportions of inputs. Whereas in one country a commodity may be produced capital-intensively, in another country the same commodity may be produced using a higher proportion of labor; this is known as *factor-intensity reversal*. Thus, the possibility of factor-intensity reversal undermines the H-O description of trade patterns between countries or regions.

How does the H-O model relate to maquiladora production? Maquiladoras are typically labor intensive. Thus, it is tempting to explain their origins using the H-O model. Weintraub (1990, p. 1150), for example, has argued that the H-O model is the most appropriate theoretical model to analyze maquiladora production. Nevertheless, the H-O model is unable to explain changes in maquiladora production across time. Although traditional maquiladoras—that is, those maquiladoras with a high use of labor and low use of capital—may fit the H-O model account, some new developments in the maquiladora sector indicate that maquiladoras are increasing their use of capital-intensive, capital-intensive technologies (Brown and Domínguez, 1989; González-Aréchiga and Ramírez, 1990, p. 24; Wilson, 1991). Furthermore, the H-O model does not explain why maquiladora production was chosen over automated production in the United States or Japan; that is, it ignores the possibility of factor-intensity reversal.

[2]Leontief's results have been further tested in other countries with mixed results. See Moroney and Walker (1966, pp. 574–576) for a brief review of international tests of the H-O model .

As an alternative to the H-O model, another model, the product-life cycle model, has been proposed. The product-life cycle model attempts to explain some of the shortcomings of the H-O model, in particular, the Leontief paradox. In addition, the life-cycle model offers a richer description of assembly production than the H-O model because it considers dynamic changes in the production process.

2.1.2 The product life-cycle model

The product life-cycle literature emerged from the works of Kuznets and Burns (Storper, 1983, 1985; Markusen, 1987; Norton and Rees, 1979). Burns and Kuznets observed that the "output of industries follows a pattern of introduction, rapid expansion, maturity, and eventual decline." (Storper, 1985, p. 268) Burns and Kuznets' ideas were later extended by other authors, most notably Vernon, to the study of international and interregional trade, and to a description of industrial locational patterns.

Storper and Walker (1989, pp. 119–122) describe two versions of the product cycle: the *product maturation and market expansion* variant, and the *production process maturation* variant.[3] In the product maturation version, firms introduce products as luxury or specialty items and are purchased by consumers with an inelastic demand. As the market for the new product develops, it becomes a mass consumption commodity, until new substitutes are introduced and foreign competition increases, thus bringing about an eventual decline in the production of the good.[4] The production-process-maturation variant analysts argue that, at first, a commodity is produced in small batches using skilled labor in an artisanal fashion (Storper, 1985, p. 268). The industry eventually standardizes the production process by introducing mechanized technology and deskilling the labor requirements, and producing large amounts of the good.

[3]Markusen (1987) has presented an alternative version, the *profit cycle model*. Her model presents important differences; nevertheless, its relationship to offshore assembly is essentially the same. Markusen's ideas are incorporated to the description presented here whenever deemed necessary.

[4]Wells (1972) applies the logic of the product maturation version of the product cycle to explain international trade patterns.

Parallel to these stages in the production process, the product life-cycle theorists consider changes in trade patterns across countries and in the locational characteristics of industrial firms. Products are at first produced in developed countries and regions where consumers are able to afford the high prices of specialized, newly-developed products. As the production process standardizes and special-purpose machinery is introduced—thus decreasing the need for skilled labor—production can be shifted to low-wage regions. In this account, therefore, a correlation between geographic dispersion and mechanization exists; consequently, exports from high-wage countries will be produced using skilled-labor intensively, and exports from low-wage regions will use more capital. Explained in this fashion, the product cycle accounts for Leontief's paradox.[5] At the same time, there is a need for market expansion to absorb the extra output generated as production standardizes. Moreover, given that many countries protect their markets from foreign exports, production is also shifted to other countries in order to gain access to their markets. As a result there is a process of industrial dispersion from developed, high-wage countries (regions) to countries (regions) where wages are lower.

The notion of industrial dispersal that stems from the product life-cycle model has made the model quite attractive in explaining increased assembly production in the developing countries. For example, Norton and Rees state:

> With the product cycle in mind, one could view LDC's [less-developed countries] as benefiting from a characteristic advantage in standardized manufacturing activities. Just as with the American periphery, the low labor costs and favorable "business climates" of such LDC's as South Korea and Taiwan attract the branch plants of multinational firms —whose hallmark is the capacity to shift production operations quickly (Norton and Rees, 1979, p. 147).

Furthermore, Grunwald and Flamm base their analysis of offshore assembly

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[5]See section 2.1.1. The relationship between the process of industrial dispersion that stems from the product life-cycle and the Leontief paradox is depicted in more detail by Wells (1972). Wells expands on the theories of Vernon. "For Vernon new products are introduced in the high-waged regions, and as they are standardized, they are located in the low-waged regions." (Storper, 1985, p. 274)

production on the product cycle:

> One way to regard the phenomenon of production abroad is as a system of production geared to retaining competitiveness for firms in developed countries after a product has entered the down side of the product cycle. That is, the firms that developed the product continue to produce economically by eventually relocating or subcontracting assembly production facilities in low-wage developing countries. (Grunwald and Flamm, 1985, p. 7)

As argued by Wilson (1989, p. 1), analysts have explained the recent economic "success" of some Asian NICs[6] (South Korea, Taiwan, Hong Kong, and Singapore) using some of the premises of the life cycle approach. Following the life-cycle rationale, those analysts claim that industry dispersal and offshore assembly helped these countries industrialize. The Asian NIC's are now capable of designing and innovating their own products. Furthermore, companies in these countries have started to transfer assembly production to other regions in Asia and the Caribbean (Grunwald, p. 1990/91) .[7] The experiences of the Asian tigers contrast with the experience of Mexico where, after almost three decades of the Border Industrialization Program, the maquiladora sector still plays a marginal role in the country's industrial structure (González-Aréchiga and Ramírez, 1990; Grunwald, 1990/91; Wilson, 1989). However, before applying the life cycle tenets to the analysis the Mexican and Latin American industrialization experiences and comparing them to the experience of the Asian countries, we must consider their particular histories. After comparing the histories of the two groups of countries, Wilson (1989, p. 2) concludes that "there is no natural, inexorable path to advanced industrialization based on the assembly industry. Rather, the reason why some countries have been able to develop on the basis of assembly industry and some have not has to do with public policy, social relations, and the historical context." Hence, the product life-cycle model may account for the movement of firms to low-wage regions, but it does not explain why nor argues that those firms will serve as a basis for industrialization.

[6]Newly-industrializing countries.

[7]According to Grunwald (1990/91), Korean firms have now set up maquiladoras in Mexico.

Moreover, Storper and Walker (1989) argue that the upsurge in assembly production cannot be fully explained by the life-cycle model. According to the life-cycle account, only those industries in the post-maturation stage would move to the developing countries. Nevertheless, the growth of personal computer (Asia) and semiconductor (Asia and Mexico) assembly contradicts the life-cycle predictions.

> Cheap labor unquestionably attracted [semiconductor] companies to Mexico, Southeast Asia or Morocco, but here was a fast growing sector that ought not to have felt pinched by factor costs [...] Neither relative factor costs nor profit cycles can alone explain this peculiar form of growth periphery. Nor can they account for the subsequent evolution of certain Southeast Asian semiconductor peripheries into more full-blown centers of design, fabrication and assembly for expanding regional markets. (Storper and Walker, 1989, p. 89–90)

On a more theoretical level, Storper (1985) criticizes the life-cycle model for its *essentialist* character. In other words, the life-cycle model presents a theory of industrial behavior based on industry characteristics at the present time. That theory is then applied to explain future developments in the world's industry. As Storper shows, the product-life-cycle theorists assume that "real technologies follow one basic path, based on increasing standardization, mechanization, and integration, which generate scale economies, reduce transportation costs, and lead to spatial decentralization." (Storper, 1985, p. 269) For example, Markusen (1987, pp. 22–23) sees mass production as the culminating stage of the cycle of production. Mass production, however, can be seen as one among several technological options—more ostensibly, flexible specialization—during the early twentieth century (Piore and Sabel, 1984; Storper, 1985, p. 272). Hence, industrial forms and technological outcomes are rather diverse and indeterminate; they are historically contingent and do not result from empirically constant characteristics of industry, as product cycle theorist claim (Storper, 1985, p. 270)[8]: "Machines are as much a mirror as the motor of social development." (Sabel and Piore, 1984, p. 5).[9]

[8]The same deterministic path for technology development is present in traditional Marxist theory, although some neo-Marxists thinkers diverge from this view. See, for instance, Marglin (1974).

[9]Historical contingency as a determinant of technological "breakthroughs" is also emphasized

2.1.3 Structural theories

Both the Heckscher-Ohlin and the life-cycle models present accounts of industrial location that can explain the growth of assembly production in the developing countries. However, both models appear to be ahistorical and lack any analysis of the social environment in which production takes place. In contrast, structural analysts view location "as a consequence of the historical and structural conditions governing the organization of industrial capital." (Storper ,1981,p. 18) Structural theorists consider the economy as a set of social relations of production and thus look at the political economy of industrial location.

In the structural account, labor plays a central role in explaining industrial location. Neoclassical economists perceive labor to be a commodity that does not differ much from other production factors; that is, its nature is only dependent on the wage level—its price—and on the productivity of labor at a specific location—its quality. In contrast, structural analysts also consider the actual ability of capital to exert control over the labor force and "the fabric of distinctive, lasting local 'communities' and 'cultures' woven into the landscape of labor." (Storper, 1983, p. 7) As a result, the structuralist view of labor is not that of a 'passive' factor of production which can be produced just like any other commodity (Storper, 1981, p. 28); instead, it acquires a spatially differentiated character to which industry responds. As industry responds to the uneven distribution of labor (and other factors) in space, it creates "typical areal or regional roles, or a 'spatial division of labor'." (Storper, 1981, p. 29)

Each industrial process exhibits a specific demand for labor power. However, fluctuations in the macroeconomic environment lead to changes in the organizational structure of production and on the nature of the labor processes involved. In this view, technical innovations involve both changes in investment on fixed capital *and* a reorganization of the labor process. As the demand for labor

by new economic theories that study the importance and ubiquitousness of increasing returns in manufacturing processes. Nevertheless, social relations are absent in this literature. See Arthur (1990) for an introduction to the subject.

with a specific set of characteristics is altered, the spatial pattern of investment changes. Consequently, the technological and locational decisions of the firm—and their ensuing implications on spatial organization—are mediated by changes in the nature of industrial capital and its relationship to labor (Schoenberger, 1987, p. 200; Storper, 1981, p. 27).

Analysts have applied the logic of structural analysis to the study of offshore assembly in several ways. Many of the existing variants coincide in indicating that there is a tendency toward an increasing dispersal of production to the Third World. First, as Clark et al. (1986) argue, the heightened international competition of today's economy is met through increased standardization of the production process, automation, and the introduction of systems such as computer-aided design and manufacturing. These changes decrease both the skill requirements and the number of workers participating in the production process, except for a small number of technicians which manage the new technologies (Clark et al., 1986, pp. 23–24). Spatially, the most labor-intensive processes are transfered to areas where low-wage unskilled and semi-skilled labor are present and where there is no previous history of labor militancy (Clark et al., 1986, p. 26).

Second, and in a similar fashion, Frobel et al. (1980) argue that a finer definition of production tasks, along with improved communication and transportation technologies and increased global competition, have pushed corporations in the industrialized countries into a cost rationalization strategy; hence, Third World countries have experienced rapid industrialization—especially in 'export processing zones'—as 'global market factories' exploit low wages and minimize production costs (Frobel et al., 1980). These authors refer to such events as the *new international division of labor.*

Third, other authors emphasize the conflictual relationship between capital and labor in the developed countries. For instance, Bluestone and Harrison (1982) see relocation from the American manufacturing belt to other locations in the Third World as a response of manufacturers to increased labor union demands. Similarly, for Sassen-Koob (1980), exporting production plants to low-wage locations helps corporations in dealing with labor shortages that threaten the profit level of firms in industrialized countries.[10] Although Sassen's argument may seem similar to the Heckscher-Ohlin account, the emphasis here is on the capital-labor relations, and not merely on cost considerations: Labor shortages are not only the result of absolute decreases in the labor force; they also result from labor activism and capital-labor conflict.

More recently, however, some authors have argued that the trend toward industrial dispersal is reversing and that, in the near future, we will witness a reconcentration of production to the core industrialized countries. The views of these authors can be framed by looking at an alternative explanation of offshore production stemming from the French Regulation School. Regulation theory looks at the institutional arrangements—or *mode of regulation*—which guarantee the survival and continuation of a given *regime of accumulation*. According to Lipietz (1986, p. 19), a regime of accumulation "describes the stabilization over a long period of the allocation of the product between consumption and accumulation." The regime of accumulation which prevailed in the developed world through the post-war era and until the early 1970s has come to be known as *Fordism*.

Fordism was characterized by tripartite *neo-corporatist* arrangements that indexed wages to productivity gains in order to sustain mass consumption. The Fordist regime came into crisis in the early 1970s, however, as a result of (i) market volatility and (ii) the exhaustion of the structural limits of the capitalist system. Market volatility originated from the social unrest of the 1960s, from supply-side shocks on the macroeconomy in the 1970s, and from the abandonment of the fixed exchange rate system in 1971. Market volatility translated into a crisis of supply, at first, and later into a crisis of demand. Furthermore, as the institutions that regulated the post-World War II economy were incapable of "accommodat[ing] the spread of mass-production technology," (Piore and Sabel, 1984, p. 166) the capitalist production system reached its own structural limits.

[10] According to Sassen-Koob (1980), another way to meet labor shortages is through labor "imports"—e.g., the *gastarbeiter* in Germany or the undocumented Mexican farm worker in the United States.

The first responses to global instability hinged upon the existing regulatory institutions (Sabel, 1989, p. 20). In addition, firms reacted to a decrease in profits by extending the logic of mass production to the Third World. In the midst of an unstable environment, firms attempted to compete through cost-cuts; "[p]roduction was reorganised to allow decentralisation of labour-intensive processes to low-wage areas" (Sabel, 1989, p. 20). According to Sabel (1989, p. 21), these old institutions and arrangements appeared incapable of reinitiating growth. A more effective response to instability came through the revitalization of the region as a coherent unit of production, to the re-emergence of flexible techniques similar to those of the nineteenth-century craft production, and to the adoption of general-purpose machinery that could be redeployed and reconfigured swiftly to adjust to changes in the market.

The effectiveness of the region is based on the assumption that, in the context of an unstable environment, cooperation between firms, workers, and government at the local level increases the competitive advantage of regional economies. Firms respond to uncertainty in the market by replacing vertical integration with a finer division of labor among firms; cooperation between firms helps spread risk among all participants and, in consequence, there are economies of scale internal to the industry but external to any single firm. Spatially, enhanced cooperation between firms leads to a convergence of production in specialized *industrial districts*.[11]

Some authors argue that the appearance of flexible production will reduce the rate at which offshore assembly has been growing during the last two decades; further, flexible production may translate into a reconcentration of production from the developing countries to the core industrialized countries (Hoffman and Kaplinsky, 1988; Sanderson, 1987; Womack, 1987). As automation and the use of flexible technologies increases, unskilled labor may become a dispensable factor. Moreover, as the need to cluster together spatially increases, corporations may find

[11]Becattini (1990) provides an extensive definition of *industrial district*. Nevertheless, his definition may only be applicable to a specific variety of industrial district that exists in Italy and other Western European countries. Different varieties of industrial districts exist; see Howard (1990) for an idealized typology of industrial districts.

it to their advantage to relocate their production facilities back to their home countries. The plausibility of such a scenario is a subject of current debate. For example, Wilson (1990a) has found that some maquiladoras are adopting flexible technologies and organizational techniques.[12] Also, Sanderson et al. (1987) and Schoenberger (1989) have allowed for the possibility that some degree of automation and flexible technologies may be adopted in the developing countries. In either case, the result is to offset the trend toward reconcentration.

Such occurrences in the global nature of production point to the need for a better understanding of the organizational and locational patterns of assembly production in the developing countries; such an understanding is essential to assess the ability or inability of those countries to offset any potentially damaging effects and to guarantee the welfare of their populations. In this thesis we assume that identifying industrial clusters is a good starting point in analyzing the prospects of maquiladora production given the changes in the global organization of production. In this light, in the next section we attempt to define a set of parameters to study the locational characteristics of assembly plants in Mexico and to identify clusters of firms and the existence of agglomeration economies.

2.2 Maquiladoras and industrial location

Thus far, we have looked at the factors that explain offshore assembly production in the developing countries; we have said nothing about the locational patterns of assembly plants at the intra-national level. Nevertheless, the resurgence of the local and regional economy as the locus of industrial production in the developed countries calls for an inquiry into the way in which global capital relates to the local economies of the developing world. If assembly plants are able to replicate some of the same organizational features being adopted at the local level in the industrialized countries, the host countries may be able to prevent a reconcentration

[12] See also Brown and Domínguez (1989) for a study on the adoption of new technologies in the maquiladora sector.

of production in the developed countries; if, on the other hand, assembly plants remain largely footloose and with no other locational pull-factor but low wages, developing countries—and regions within those countries—will be susceptible to the vagaries of global industrial production. Hence, an understanding of the spatial configuration of offshore manufacturing within the developing countries is essential.

Earlier, we argued that the locational decision process for a maquiladora involves several stages. Now we discuss some of the locational determinants that maquiladoras may face once they settle in Mexico. In particular, the theoretical rationale for spatial concentration is presented in this section. The discussion presented here revolves mainly around location theory as presented by neoclassical economists, despite the fact that other non-economistic, institutional and political, factors may influence a firms location decision.

2.2.1 Neoclassical location theory

Neoclassical economists view the economic system as the sum of discrete rational economic agents—consumers and firms—interacting in the market as they exchange goods and services. Rationality in the neoclassical account implies that agents maximize the net benefits they obtain from market transactions: consumers maximize a subjective *utility function* subject to income constraints, while firms maximize profits subject to a given production function. An efficient allocation of resources is reached as agents rationally respond to commodity-price signals so as to maximize utility and profits.

Neoclassical economists extend their general assumptions to the analysis of the location decision of firms. In the neoclassical location account, firms choose to locate in places where profits are maximized. A firm's profits become a function of the characteristics of a particular locality. The profit level will be determined by the production and transportation technologies available at a location, as well as by the geography of demand and resources. Production technology will determine the relative amount of each input used in the production of a given good and the substitutability among inputs. It will also determine whether the weight—the major component of transport costs—of the final good is greater (*weight-gaining* technology) or smaller (*weight-losing* technology) than the aggregate weight of the inputs used[13]. In addition, the types of transportation modes available at each location will have an impact on the price of inputs and final goods. Thus, both revenue and costs will vary from location to location: total revenues will be a function of the demand for a firm's output, which is in turn determined by the spatial distribution of consumers relative to the location, and by the *delivered* price of its products—that is, price *plus* transport costs; total costs will be a function of the price and quality of inputs at the location.

Firms can be classified according to the relative importance of different variables in their revenue and cost functions (Alonso, 1975). Thus, a firm is said to be *transport-oriented* when transportation costs are relatively high; if such is the case, firms would attempt to minimize transportation costs by locating in places with inexpensive access to transportation networks such as highways or waterways. If transportation costs are not very high, other factors may be more important in pulling firms to a particular location. *Power-oriented* firms are those that consume large amounts of electricity or other forms of energy and will locate in regions and localities where energy sources are abundant and inexpensive. Firms are said to be *market-oriented* when they locate near centers of final demand; weight- gaining industries are typically market-oriented since transport costs are minimized at the point of final consumption. On the other hand, weight-losing firms—e.g., steel mills—will locate near input sources, and so they are said to be *material-oriented*. Finally, industries that require large numbers of workers, or workers with a specific characteristic, are called *labor-oriented*. For example, maquiladoras are (low-wage) labor-oriented, because they require a vast supply of low-wage labor.

When no particular factor is of importance in the locational decision of an

[13] It may be hard at first to conceive how a given technological process might be weight-gaining. A gain in weight occurs, for example, when a ubiquitous public good (e.g., water) is used in the production of a commodity. Since the public good is assumed to be present at all locations and since, by definition, it is free, the weight of the resulting commodity may exceed the aggregate weight of all other inputs into the production process. The soft-drink industry is weight-gaining: it is cheaper to transport sugar—the raw material into beverage production—than to transport the final product.

industry, or when the main input is ubiquitously found, the industry is considered to be *footloose*. As defined by Alonso (1975, p. 33), footlooseness implies that, as technological progress decreases transportation cost and input requirements, industries and firms will tend to disperse. Alonso (1975, p. 33) assumes that footlooseness is largely a result of low transport-costs, but that other factors may still be of importance in influencing a firm's location decision. One such location factor that, according to Alonso, offsets footlooseness is the need for firms to maintain contacts among each other to adapt to market trends more rapidly, thus favoring concentration. The existence of concentrations of firms and industries implies that external agglomeration economies exist. As noted by Alonso (1975, p. 35), in a rather contradictory manner, external economies of agglomeration posit some problems for neoclassical location theory, at least in its conventional form.

2.2.2 Agglomeration economies

The existence of agglomerations of industries has attracted the attention of neoclassical economists since the days of Alfred Marshall (c. 1890). Marshall--one of the founders of modern microeconomic theory—was astonished by the existence of several *industrial districts* in nineteenth-century England (Harrison, 1990; Krugman, 1991a; Sabel, 1989). It is surprising then that a rigorous analysis of agglomerations was absent from neoclassical economic theory until recently. According to Krugman (1991a), the absence of studies on industrial agglomeration was explained by the lack of appropriate mathematical tools. Neoclassical economics, based on the assumption of constant returns to scale and perfect competition, was unable to handle the widespread existence of external economies of industry scale that arise from concentration; nor was it able to deal with a world of increasing returns and positive feedbacks.[14] Unable to adopt the mathematical rigorousness that neoclassical economics demands, neoclassical location theory became relegated *vis-a-vis* other fields in economics. Recently, however, the

[14]For a discussion of the importance of external economies and increasing returns in economic theory see Arthur (1990).

incorporation of the analysis of increasing returns into such fields as international trade has renewed the interest of economists in economic geography.[15]

Despite its lack of a rigorous mathematical specification, Marshall and other economists identified several forces that drive agglomeration. According to Isard (1975, p. 113–117), those forces can be classified in three groups: internal economies of scale, urbanization economies, and localization economies. First, *internal economies of scale* of a firm will decrease average costs as the size of the firm increases. Economies of scale occur whenever the production process involves large fixed costs such that average costs fall with increased production. A firm would find it profitable to locate wherever it could operate at a large scale. Thus, large concentrations of industries, population, and other activities will foster a concentration of firms that present economies of scale.

Second, *urbanization economies* are associated with a large population and the high level of overall economic activity present in urban centers. Urbanization economies benefit and "are available to all firms in all industries" (Isard, 1975, p. 116). Furthermore, they result merely from the size of the city and not due to its industrial composition (Henderson, 1986, p. 48). Firms benefit from an enhanced availability of diverse and specialized goods and services, and from a larger labor pool. In addition, public services may be supplied at a lower cost and with a better quality.

Third, and last, *localization economies* refer to economies that accrue to all firms in an industry at a particular location as the output of the industry increases. "These economies reflect (i) economies of intraindustry specialization where greater industry size permits greater specialization among firms in their detailed functions, (ii) labor market economies where industry size reduces search costs for firms looking for workers with specific training relevant to that industry, (iii) scale for 'communication' among firms affecting the speed of, say, adoption of new

[15]The application of increasing returns and external economies to trade theory was pioneered by Helpman and Krugman (1985). Recently, Krugman has extended that analysis to the study of the importance of space in economic life (Krugman, 1991a, 1991b).

innovations [16], and (iv) scale in providing (unmeasured) public intermediate inputs tailored to the technical needs of a *particular* industry." (Henderson, 1986, p. 47–48)

Alonso, in his account of external economies of agglomeration, implicitly assumes that spatial concentration is a deterrence of the enhanced footlooseness of firms as a result of transport cost abatement. In fact, a fall in transport cost will be a stimulus, not a hindrance, to localization (Krugman, 1991a). Furthermore, localization does not depend on an asymmetry of transportation costs between intermediate and final goods. "[L]ocalization will tend to occur unless the costs of transporting intermediates are particularly *low* compared with those of transporting final goods. And a general reduction of transport costs, of both intermediate and final goods, will ordinarily tend to encourage localization rather than discourage it." (1991a, p. 50) The implication for location theory is that, rather than witnessing a dispersion of production as a result of advances in transportation technology, a renewed drive toward spatial concentration may indeed occur.

2.3 Research implications

The future of maquiladora production in Mexico—and of offshore assembly elsewhere—is tied to changes in the international economy. Hence, an understanding of changes in the global structure of industrial production is essential in assessing the future of those countries and communities where assembly plants predominate. Nevertheless, parallel to such an understanding, it is also essential to study the structure and characteristics of assembly production at the local level, that is, to study how assembly plants and maquiladoras relate to the local economy of the cities where they locate.

Currently, the emphasis on flexible forms of production that rely on automated, general-purpose machinery and on a closer cooperation between firms has led some authors to question the viability of assembly production in the developing world (Hoffman and Kaplinsky, 1988; Sanderson, 1987; Sanderson et al.,

[16] Krugman (1991a: 52) refers to this as "technological spillovers".

1987; Womack, 1987). Spatially, the implications of those changes are a clustering of firms at the region and city level and the formation of industrial districts in the developed countries. If indeed the emergence of flexible production can be seen as a new paradigm of industrial development, its implications for the Third World should receive deep academic and policy consideration.

If the maquiladora sector remains a labor-intensive production strategy, where the use of advanced, flexible technology is rare, and where cooperation among firms is absent, a relocation back to the industrialized core may indeed occur. However, if maquiladoras are able to introduce new technologies and to cooperate with other maquiladoras and with the local domestic industries of the communities where they locate, relocation will be less likely to occur. Furthermore, if maquiladoras establish forward and backward linkages with local firms, and if other types of linkages exist—e.g., labor up-skilling, technology transfer—relocation will not only be impeded, but maquiladora production may turn into a catalyst for local economic growth.

Identifying industrial clusters of maquiladoras where external economies of localization exist provides evidence on which industries have been able to create linkages to the host community other than the use of cheap labor. In other words, the existence of localization economies implies that low wages are not the sole maquiladora locational determinant anymore, but that the availability of local suppliers and of specialized labor skills are important locational pull factors as well. As a result, the maquiladoras' footloose character is offset and the possibility that they return to their host countries is greatly diminished. Therefore, in the following chapters, we try to identify industrial clusters of maquiladoras and test for the presence of localization economies.

Chapter 3

Geographic profile of maquiladora production

In this chapter we analyze the spatial profile of assembly production, reviewing data for 17 urban areas in Northern Mexico that account for a large proportion of total maquiladora activity in the country. We apply different techniques to study the extent to which industrial concentration in the maquiladora sector occurs and compare this concentration to industry and city characteristics.

3.1 Techniques

In this section, we present several techniques for identifying clusters of firms in the maquiladora sector: (i) the location quotient and related coefficients, (ii) the specialization and localization coefficients, and (iii) shift-share analysis. First, the location quotient permits identifying concentrations of firms or employment in a city that are above the national average. Second, the localization coefficient measures the extent to which an industry is concentrated across the cities or regions under consideration. Third, the specialization coefficient is an index of the extent to which a city's industrial mix differs from the industrial distribution of the country as a whole. These techniques are highly descriptive. They are helpful in identifying geographical clusters and the tendency of certain industries to concentrate in space, but they do not provide any further insight on why concentrations may arise. Nevertheless, they are a useful indicator of which industries and regions should receive closer attention when studying the determinants of concentration.

3.1.1 The location quotient

The first technique is known as the location quotient. Bendavid-Val (1983, p. 75) characterizes the location quotient as "...a device for gauging the relative specialization of a region in selected industries." In its simplest form, the location quotient compares the relative weight of a particular industry in a region to its relative national weight. Such weights are typically measured as the share of employment at the regional or national levels accounted for by an industry, but a number of other measures exist. The location quotient is a simple descriptive technique that requires readily available data; "[it] is useful in the early exploratory stages of research." (Isard, 1967, p. 125) However, its simplicity also accounts for most of its limitations; as Isard (1967, p. 125) puts it, "the fact that a region has more or less than its 'proportionate' share of an activity does not, of itself, tell us much." Thus, in the study of industrial concentration, the location quotient will serve as a first measuring rod and as an indicator of the regions and industries that demand special attention.

Algebraically, the location quotient LQ_{ir} of industry i in region r is given by

$$LQ_{ir} = \frac{\frac{e_{ir}}{RV_r}}{\frac{E_i}{RV_N}}, \tag{3.1}$$

where e_{ir} is employment in industry i $(i = 1, ..., n)$ in region r $(r = 1, ..., m)$; E_i represents employment in industry i in the nation; and RV_r and RV_N are reference variables for industry i in region r and in the nation, respectively. The reference variables RV_r and RV_N are typically (but not neccesarily) given in terms of total employment in region r and in the nation, respectively.

We can make several observations about Equation (3.1). First, there is no particular reason why employment data should be used; its use is explained by the relative ease with which employment data can be obtained. Alternatively, other measures of industrial activity can be used. For example, we can weigh the importance of an industry in the region (nation) by the share of the industry in total regional (national) value added. Second, the reference variable RV and variable e do not necessarily have to be expressed in the same terms. We can use the location quotient, for instance, to compare industrial productivity across regions. In this case, the specialization variable e could be given in terms of value added and the reference variable RV in terms of employment —that is, value added per worker-hour or productivity. Third, we can not only compare regional data to national data; we can also compare regional data to "a parent region or province, a median or average of other regions, a nation exclusive of the study region, or even a group of linked nations." (Bendavid-Val, 1983, p. 77) Finally, we can use different versions of Equation (3.1) to measure specialization in many different areas of study.

For the purpose of studying industrial concentrations of maquiladoras we use the following variants of the location quotient:

- The share of value-added per industry in each municipality relative to the industry's share of total national value added in the maquiladora sector.
- The share of employment per industry in each municipality relative to the industry's share of total national employment in the maquiladora sector.
- The proportion of firms in an industry at the municipal level relative to the proportion of firms in the industry at the national level.

In all cases, if $LQ_{ir} > 1$, then, municipality r shows a larger proportion of employment in industry i than the nation; if $LQ_{ir} = 1$, the proportion of employment in the municipality is identical to the national proportion; finally, if $LQ_{ir} < 1$, the proportion of i's employment in the region is below the national average. Scott (1988a. p. 49) uses instead a $LQ_{ir} \geq 1.2$ to indicate overrepresentation of the industry in the municipality or region, and a $LQ_{ir} \leq 0.8$ to show underrepresentation. Scott's criteria are used in this study and industrial concentration is defined as overrepresentation in the proportion of employment or value added in the industry (i.e., $LQ_{ir} \geq 1.2$).

In addition, we present two extensions of the location quotient: the localization coefficient and the specialization coefficient.

The Localization Coefficient

Isard (1967, pp. 251–252) defines the localization coefficient as "a comparison of the percentage distribution by region of employment in the given industry with the regional percentage distribution of the base magnitude, for example total national manufacturing employment." In other words, the localization coefficient is an index of the extent to which the share of industry i's employment across regions (e_{ir}/E_i) deviates from the share of total employment in each region (RV_r/RV_n).

Algebraically, the localization coefficient LC_i is given by

$$LC_i = \frac{1}{2}\sum_{r=1}^{m}\left|\frac{e_{ir}}{E_i} - \frac{RV_r}{RV_N}\right|, \tag{3.2}$$

where LC_i is the localization coefficient for industry i across all m regions; all other notation parallels that of the location quotient LQ_{ir} [Equation (3.1)].

When industry i is evenly distributed across all m regions,

$$\frac{e_{ir}}{E_i} = \frac{RV_r}{RV_N} \tag{3.3}$$

for all regions, so that the localization quotient is equal to zero. On the other hand, if industry i is completely concentrated in some region r, $e_{ir} = E_i$, and if region r is relatively small $(RV_r << RV_N)$, the localization coefficient will approach 1.

The name localization coefficient might be misleading. As mentioned, the localization coefficient is only a measure of relative regional concentration; it does not indicate the existence of *localization economies.* Indeed, the localization coefficient says nothing about why those concentrations exist; thus, it is only a descriptive tool. Furthermore, the localization coefficient is useful in that it shows which industries might tend to concentrate, but it does not tell us in which regions. For that purpose, we might rely on other measures (e.g., location quotients).

The Specialization Coefficient

The specialization coefficient is similar in nature to the localization coefficient. Whereas the localization coefficient shows the relative concentration of an industry—without saying anything about where it concentrates—the specialization coefficient "measures the extent to which the distribution of employment by industry classes in [a] given region deviate from such distribution" in the nation as a whole (Isard, 1967, p. 271). However, the specialization coefficient does not specify which industries predominate in the region.

In studying industry localization in Europe and the United States, Krugman (1991a, p. 76) uses a similar measure, which he terms "index of regional divergence." In this study, we use elements of both Isard (1967) and Krugman (1991a) to construct the following index:

$$SC_r = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{e_{ir}}{RV_r} - \frac{E_i}{RV_N}\right|, \tag{3.4}$$

where SC_r is the specialization coefficient for region r in one or all n industries; all other notation is similar to that of the location quotient.

Again, the specialization coefficient is bounded by 0 and 1. If $SC_r = 0$, region r has an industrial mix proportional to that of the nation, that is, employment in the region across industries is distributed proportionately to the national employment distribution. On the other hand, if all of region r's employment is concentrated in one particular industry, SC_r approaches 1.

3.1.2 Shift-share analysis

Ideally, in a study of geographic industrial agglomeration, we should pay attention to the changes in the spatial characteristics of the industry over time. For example, we would like to test whether a region has been experiencing an "above-average" increase in employment in a given industry during a particular period of time. Also, we may need to distinguish between absolute and relative increases across industries in different regions. Shift-share analysis effectively tackles these issues.

Shift-share analysis decomposes region r's employment growth in industry i into three different components:

National Share (NS_{ir}) The national-share component represents industry i's growth in region r attributable to natural growth across all industries; that is, industry i in region r is assumed to grow at the same rate as total national employment.

Industry Mix (IM_{ir}) The industrial-mix component accounts for the growth in industry i in region r attributable to the growth rate of the industry at the national level. The IM component assumes that any industry i grows at the same rate in region r and in the nation as a whole.

Regional Shift (RS_{ir}) The regional-shift component captures the increase in industry i's employment that stems from the difference in the growth rate of i at the regional and national levels.

Algebraically, these components are given by:

$$NS_{ir} = e_{ir}^{t-1}\left(\frac{E^t}{E^{t-1}}\right) \tag{3.5}$$

$$IM_{ir} = e_{ir}^{t-1}\left(\frac{E_i^t}{E_i^{t-1}} - \frac{E^t}{E^{t-1}}\right) \tag{3.6}$$

$$RS_{ir} = e_{ir}^{t-1}\left(\frac{e_{ir}^t}{e_{ir}^{t-1}} - \frac{E_i^t}{E_i^{t-1}}\right) \tag{3.7}$$

Employment in industry i in region r at the beginning of the period of analysis is given by e_{ir}^{t-1}; at the end of the period, it is given by e_{ir}^{t}. The national employment level in the industry at the beginning of the period is given by E_i^{t-1}; at the end, it is given by E_i^t. Finally, national employment in all industries at the beginning and at the end of the period is given by E^{t-1} and E^t, respectively.

The aggregate effect of all three components yields the actual employment level of industry i in region r at some time t:[1]

$$e_{ir}^t \equiv NS_{ir} + IM_{ir} + RS_{ir}. \tag{3.8}$$

Identity (3.8) can be re-written as

$$e_{ir}^t = RP_{ir} + RS_{ir}, \tag{3.9}$$

where $RP_{ir} = NS_{ir} + IM_{ir}$. RP_{ir} is the Regional Proportion or Share, and "it expresses the number of employees expected in industry i in the region if the industry were to grow at the same rate regionally as nationally." (Stevens and Moore, 1980, p. 420) Since our interest lies in identifying the formation of concentrations over time, the term of interest for our purposes is RS_{ij} the regional-shift component (or *shift ratio*).

According to Stevens and Moore (1980, p. 419), "[t]he regional shift component is intended to provide a measure of the relative performance of the region in a particular industry." If the regional shift component is positive, it indicates that the region has a "comparative locational advantage" (Stevens and Moore, 1980, p. 419) for the industry *vis-a-vis* other regions. Thus, if $RS_{ir} = 0$, $e_{ir}^t = RP_{ir}$: regional employment in the industry has increased at the same rate as the nation. On the other hand, if $RS_{ir} > 0$, employment in industry i at region r has grown faster than industry i 's national rate. A positive regional shift indicates then that there are certain factors that favor locating in the region relative to other regions; these factors may be a possible cause of concentration. Nevertheless, we cannot use shift-share analysis to provide an answer to what those factors might be; it is only a descriptive technique.

[1] Shift-share analysis has also been used to forecast employment growth into the future. For a review of the forecasting application of shift-share, see Stevens and Moore (1980).

3.1.3 Use and limitations

So far, we have presented several techniques for identifying concentrations. Their usefulness and appropriateness to this study are justified since these techniques provide a quick and easy way to identify concentrations with few data requirements. In order to analyze the results obtained from applying these techniques, we discuss the experience of five maquiladora industries. Results are presented in Appendix B.

We compared both the location quotient of an industry and the specialization coefficient of the cities in the sample to some characteristics of the city—population size, maquiladora employment, among others—and of the industry in the city—percent of domestic inputs used by the industry, percent of technical workers. The choice of these characteristics was determined by data availability. We ranked cities by the size of the location quotient or specialization coefficient, and by the size of one of the city or industry characteristics—e.g., population size, percent of technical workers. We then computed the rank correlation and tested for significance.

Rank correlation helps us determine why industries might be concentrating. If, for example, the correlation between the size-rank of the location quotient and the population-size rank is positive, urbanization *might be* present; thus, population size is a proxy for urbanization economies. Similarly, a positive correlation between the LQ-rank and the domestic input use or technical employment at each location may show that these factors are important locational determinants. Given that input and skilled-labor availability are among the determinants of industrial localization, we used domestic input and technical employment as proxies for localization determinants. It is impossible, however, to make cause-effect observations from rank-correlation results; rather, they only help us pinpoint some of the factors driving concentration and hinting to the existence of localization or urbanization economies, prior to econometric analysis. Furthermore, a shortcoming of the rank correlation technique is that it ignores the possibility of significant correlation between some of the variables against which location quotients are compared. If two variables are correlated, they will present similar correlation coefficients with respect to the location quotients.

In addition to location quotients and specialization coefficients, we computed localization coefficients. Rather than providing an index of industrial concentration with respect to the country as a whole, the localization coefficient is only a measure of the extent to which a city is concentrated *in the sample of cities used in this study.* In order to obtain nationally significant figures, data for all maquiladora localities in the country would have been needed; thus, the figures presented in this study are significant in as much as the cities considered in this study are the largest maquiladora centers in Mexico. We considered an alternative technique, the *locational Gini coefficient* (Krugman, 1991a), to measure the degree of spatial concentration of the industry and compared against localization coefficients. Locational Gini coefficients proved redundant to the localization coefficient and are therefore not included in the thesis.

Due to data limitations, we could undertake shift-share analysis only to study differences in growth between border and non-border localities. Ideally, we would have used it to identify growth trends for different industries at the city level and to determine which industries might present a tendency to concentrate. Nevertheless, the lack of disaggregated time-series data for different cities prevented such an analysis.

Finally, as pointed out by Isard (1967, pp. 262–270), several technical and conceptual limitations apply to all of the techniques presented thus far. First, the coefficient and curve of localization, as well as the regional-shift ratio, will depend on the "degree of fineness" of the geographic subdivisions being used —states, cities, municipalities, etc. Second, the value or shape of any of these measures will depend on the level of industrial disaggregation used. Third, with regard to the regional-shift component, Isard (1967, p. 259) points out that regional changes in variables such as population, value added per industry, public spending, and private investment affect the meaning and implication of the shift ratio. Finally and most important, all the devices analyzed "are of little value in identifying or evaluating cause and effect relationships. They can assist the analyst to perceive certain general empirical associations, but can be considered only as rough guideposts for basic regional analysis and planning." (Isard, 1967, p. 270)

3.2 Data

As stated earlier, data limitations have prevented researchers from undertaking the study of regional differences in maquiladora production. In particular, data with a sufficient degree of industrial disaggregation at the municipal level have not been published by the Mexican government's *Instituto Nacional de Estadística, Geografía e Informática* (INEGI) due to confidentiality restrictions. For the purposes of this thesis, however, we use municipal data with a finer degree of disaggregation. We obtained the data under a special agreement with INEGI. The data we use provide detail on the number of firms, total employment by class, value added in Mexico, use of domestic inputs, among others, by industry per municipality.

We looked at five industries in the maquiladora sector spread across 17 Mexican cities. The industries we analyze are the largest industries in the maquiladora sector; they include: (i) *electric and electronic components*; (ii) *electric and electronic goods and equipment*; (iii) *transportation equipment*; (iv) *textiles*; and (v) *furniture assembly*; other industries are also analyzed in some cases.[2] The cities analyzed are the largest maquiladora production centers in the country; they include 11 border cities (Matamoros, Nuevo Laredo, Reynosa, Acuña, Piedras Negras, Juárez, Agua Prieta, Nogales, Mexicali, Tecate, Tijuana) and 6 cities in the interior of Mexico (Monterrey (metropolitan area), Saltillo, Torreón (metropolitan area), Chihuahua, Hermosillo, and Ensenada). These 17 cities account for 84% of all maquiladora employment and 63% of all plants.

The sample choice was determined by the need to look at cities where industrial concentrations might have developed the farthest. Including other cities might not have been useful since they would have presented only scattered

[2]See Appendix A for a complete listing of the maquiladora sector's industrial categories as defined by INEGI.

maquiladora plants without considerable industrial clustering.[3]

3.3 Geographic profile—results

In this section, we apply the techniques presented above to the study of industrial concentration in maquiladora production. As a first step, we present a brief description of growth behavior in the maquiladora sector over the last decade; in the process, we look at differences in employment growth across industries and regions, particularly between border and non-border municipalities. Such a description serves as a preamble to an industry-by-industry discussion of industrial concentration across a sample of cities.

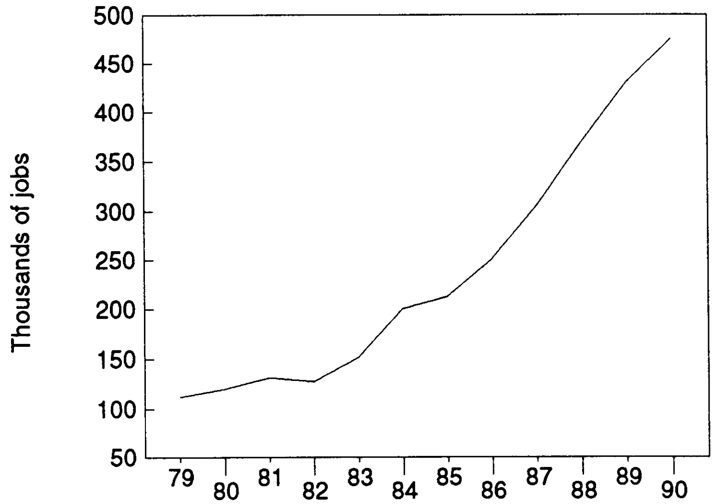
3.3.1 Growth patterns

Since its outset in the mid 1960s, the maquiladora sector has increased steadily. Nonetheless, as shown in Figure 3-1, a rapid increase in employment growth occurred after 1982: in 1983 employment grew by 18.7% and in 1984 by 32.5% (Table 3.1). Such increases followed the Mexican government's announcement that it was unable to service its foreign debt. In order to curtail the astronomical capital flight underway, the government drastically devaluated the Mexican peso against the U.S. dollar. Recurring devaluations of the peso during the 1980s, coupled with high inflation, slashed Mexican real wages by 50%: Mexican wages suddenly became an attractive bargain for U.S. firms. To illustrate, Fernández-Kelly (1987) estimates that, in dollar terms, from January to September 1982, monthly wages in Juárez fell from $364 to to $156. As a result, Mexico became a preferred location for assembly operations.

Growth in the maquiladora sector presented differences across industries, however. Table 3.2 presents growth patterns for 6 maquiladora industries from 1981

[3] One important city that could have been included in this study but for which data could not been obtained is Guadalajara. Wilson (1990b) has studied maquiladoras in Guadalajara in an attempt to identify linkages between them and the local economy.

Figure 3-1: Growth in maquiladora employment (1979–1990)



Source: INEGI.

Table 3.1: Growth in the maquiladora sector (1979–1990)

Year	Basic Indicators # Firms	# Workers	Annual % change	Cumulative % change
1979	540	111,365	--	--
1980	620	119,546	7.3	7.3
1981	605	130,973	9.6	17.6
1982	585	127,048	-3.0	14.1
1983	600	150,867	18.7	35.5
1984	672	199,864	32.5	79.5
1985	760	211,684	5.9	90.1
1986	890	249,833	18.0	124.3
1987	1,125	305,253	22.2	174.1
1988	1,396	369,489	21.0	231.8
1989	1,655	429,725	16.3	285.9
1990	1,938	475,762	10.7	327.2

Source: Calculated from INEGI data.

Table 3.2: Growth in selected maquiladora industries (1981–1989)

Region	1981		1989		% Change	
	# firms	# workers	# firms	# workers	# firms	# workers
National total	605	130,973	1,655	429,725	173.6	228.1
Textiles	117	18,059	245	39,077	109.4	116.4
Shoe and leather (1984)	35	3,933	49	8,090	40.0	105.7
Furniture	54	3,319	219	21,384	305.6	544.3
Transportation equipment	44	10,999	142	90,524	222.7	723.0
Electric/electronic goods	67	33,396	116	63,200	73.1	89.2
Electric/electronic components	163	42,791	348	103,461	113.5	141.8
Services	26	6,787	72	18,822	176.9	177.3
Border municipalities	533	116,450	1,327	339,918	149.0	191.9
Textiles	92	14,278	152	20,672	65.2	44.8
Shoe and leather (1984)	32	3,648	42	7,298	31.3	100.1
Furniture	51	3,236	219	21,384	329.4	560.8
Transportation equipment	41	10,108	113	75,765	175.6	649.6
Electric/electronic goods	60	31,801	93	53,463	55.0	68.1
Electric/electronic components	145	36,935	308	87,079	112.4	135.8
Services	20	5,105	58	15,269	190.0	199.1
Non-border municipalities	72	14,523	328	89,807	355.6	518.4
Textiles	25	3,781	93	18,405	272.0	386.8
Shoe and leather (1984)	3	285	7	792	133.3	177.9
Furniture	3	83	n.a.	n.a.	n.a.	n.a.
Transportation equipment	3	891	29	14,759	866.7	1556.5
Electric/electronic goods	7	1,595	23	9,737	228.6	510.5
Electric/electronic components	18	5,856	40	16,382	122.2	179.7
Services	6	1,682	14	3,553	133.3	111.2

Notes: (1) n.a. = not available.
(2) For the shoe and leather industry, 1984 figures are used instead of 1981 figures.
Source: Calculated from INEGI data.

to 1989; although all industries grew during this period, two of them, *transportation equipment* and *furniture*, grew at a faster rate than the national average. The employment share of the transportation equipment industry went up from 8.4% of national maquiladora employment to 21.1% and that of the furniture industry doubled from 2.5% to 5.0%. As a result, the employment share of other industries declined: in the *electric and electronic components* industry, the share of employment fell from 32.7% to 24.1%; in the *textile* industry, it fell from 13.8% to 9.1%; and in the *electric and electronic goods* industry, the employment share declined from 25.5% to 14.7%.

In addition, maquiladora growth presented differences across regions. Whereas in the past maquiladoras were restricted to operate along the border, they are now allowed to operate anywhere in Mexico. In turn, employment growth was not restricted to border municipalities, but spilled into the Mexican hinterland. Indeed, the employment growth rate in the interior of Mexico surpassed the growth level in border municipalities; from 1981 to 1989, employment in the maquiladora sector grew at an average annual rate of 64.5% in non-border localities *versus* 24.0% in border localities. In absolute terms, border maquiladora employment increased by more than 220,000, while non-border maquiladoras contributed more than 75,000 jobs, or approximately one quarter of all new maquiladora jobs (Table 3.2).

Again, the employment growth rate differed across industries in each region. In order to understand the regional impact of different industrial growth rates, we use shift-share analysis. Table 3.3 shows a decomposition of growth factors affecting each industry in border and non-border municipalities. We could not undertake a more detailed analysis of shifts in the industrial characteristics of particular cities due to the lack of disaggregated industrial data at the municipal level for periods previous to 1990 prevented. Nevertheless, we can make several observations from border *versus* non-border data. First, the regional-shift components for each region confirm that maquiladora production is increasingly spreading into the interior of Mexico; such an observation holds true for all industries with the exception of service maquiladoras. In contrast, for border municipalities, we observe that positive regional shifts occurred only for the furniture and service industries.[4] Second, despite the fact that changes in the industrial distribution affected several industries, regional growth in non-border municipalities was large enough in several cases so as to offset industrial mix changes (i.e., $RS > |IM|$); such was the case of the textile and electric/electronic goods industries, implying that both industries are increasingly spreading into the Mexican interior (Table 3.2). Third, the positive regional-shift component for all industries in non-border municipalities questions the idea that only "traditional" maquiladoras, that is, those that perform simple labor

[4] 1989 figures for non-border maquiladora plants in the furniture industry were not available, perhaps due to confidentiality restrictions; INEGI assumes that employment in border municipalities equals national employment for the industry. It would be expected, then, that the regional shift component for border municipalities is positive, given the positive absolute growth of the industry.

Table 3.3: Shift-share decomposition of maquiladora employment growth (1981–1989)

Region Industry	National Shift	Industrial Mix	Regional Shift	Employment
Border	382,075	0	(42,157)	339,918
Textiles	46,846	(15,951)	(10,223)	20,672
Shoe and leather (1984)	11,969	(4,465)	(206)	7,298
Furniture	10,617	10,232	535	21,384
Transportation equipment	33,165	50,026	(7,426)	75,765
Electric/electronic goods	104,340	(44,158)	(6,719)	53,463
Electric/electronic components	121,184	(31,882)	(2,223)	87,079
Services	16,750	(2,592)	1,112	15,269
Non-border	47,650	(5,258)	47,414	89,807
Textiles	12,406	(6,931)	12,931	18,405
Shoe and leather (1984)	935	(365)	222	792
Furniture	n.a.	n.a.	n.a.	n.a.
Transportation equipment	2,923	3,755	8,080	14,759
Electric/electronic goods	5,233	(2,552)	7,056	9,737
Electric/electronic components	19,214	(5,407)	2,576	16,382
Services	5,519	(488)	(1,478)	3,553

Notes: (1) Figures in brackets represent negative numbers.
(2) n.a. = not available.
(3) 1984 figures for the shoe and leather industry are provided.
Source: Calculated from INEGI data.

intensive processes—e.g., textiles—tend to locate in the Mexican hinterland; shift-share results call at least for firm-by-firm studies to dispel that question.

3.3.2 Industrial concentration

We computed location quotients and localization coefficients for five maquiladora industries. The results for each industry are presented next, along with evidence for or against agglomeration factors—i.e., urbanization and localization economies.

Textiles

In 1981, the textile industry occupied the third place in maquiladora production, behind the electric/electronic goods and electric/electronic components industries, with 18,059 workers (Table 3.3). By 1990, the industry employed more than 42,000 workers, but had fallen behind the transportation equipment industry in importance. Although the industry grew at an average rate of 14.5% from 1981 to

1989, it failed to keep up with the 28.5% total maquiladora employment growth during the same period.

The industry, nevertheless, presented noticeable growth differences between border and non-border municipalities. Whereas textile employment along the border increased by only 65% during this period, it grew by 272% in non-border municipalities. As a result, while non-border municipalities accounted only for 20.9% of textile employment, in 1989 they accounted for 47.1%. Although the employment share of non-border municipalities for other industries also increased, none of those industries reached the level of the textile industry. Ranfla and Avilés (1988, as cited by Quintanilla (1991)) point to the case of the textile industry to indicate that "traditional" maquiladoras tend to move inland, while "modern" maquiladoras locate in border localities. Although textile maquiladoras may be easily considered "traditional" due to its labor intensiveness and low value added per worker, we may question the rationale for the above claim given the high growth rates in the interior of Mexico of other industries that cannot be easily classified as traditional and, at least, suggest the need for detailed case studies.

In 1990 15 out of 17 cities in the sample had textile maquiladoras operating. Employment in these 15 cities amounted to 33,264 workers or 79.1% of total employment in the industry. Concentration of textile maquiladoras, as measured by the employment location quotient ($LQ \geq 1.2$), existed in four cities: Torreón, Piedras Negras, Mexicali, and Hermosillo; moreover, if, instead, the value added-LQ is considered, Agua Prieta and Nogales also present concentrations of textile maquiladoras. Textile maquiladora employment in the top four cities reached 32.8% of national textile employment.

Textile assembly and manufacturing presents a remarkably high LQ in the Torreón-Gómez Palacio-Lerdo metropolitan area, located in the Mexican interior. It was found that, out of 51 maquiladoras in the area, 44 were textile firms, yielding a high LQ in terms of firms; value added and employment LQs were even higher, implying that firms in the region were relatively larger than the average textile maquiladora in the rest of the country; indeed, the average size of local textile plants was 169 workers *versus* 146 workers at the national level. The Torreón-Gómez Palacio-Lerdo region is well-known as a cotton-producing center in Mexico. Thus, we can possibly explain the high concentration of textile maquiladoras by the availability of local inputs to the industry. Nevertheless, textile maquiladoras in the region presented a lower value added in Mexico than the typical textile firm in the country, suggesting that local inputs may not be significant. In addition, a careful look at the ratio of domestic inputs to total inputs exhibited a lower ratio for maquiladoras in the region than for the national average textile maquiladora. As a result, the importance of local inputs as an agglomeration factor is not supported by the available data.

Piedras Negras, a border town in the state of Coahuila, presented the second highest LQs in the textile industry of any other city in the sample; interestingly, Acuña, another border town in the same state showed very low LQs in the industry. This indicates that the locational determinants for textile firms may be location-specific rather than depending upon characteristics of the larger region in which they locate.

The location quotients for the textile industry do not show a significant rank-correlation with either city characteristics or characteristics of the industry at the location (Table 3.4). The only exception is the percent of technical workers employed by the industry in each city, when compared to value-added location quotients. Consequently, we cannot make any definitive claims about how concentration is affected by industry and city characteristics. Nevertheless, by looking at the correlation coefficients' sign and magnitude, we can infer some qualitative characteristics of industrial concentrations. We can then use such qualitative information to interpret the econometric results presented in Chapter 4, keeping in mind that, by themselves, the insignificant correlation coefficients tell us nothing.

With these considerations in mind, we first observe that the size of the employment LQ presented a positive, yet statistically insignificant, correlation coefficient with respect to population size, suggesting the existence of some degree

Table 3.4: LQ rank-correlation vis-a-vis city and industry characteristics.

Industry	LQ expressed in terms of:	City and industry characteristics: Population	Maquiladora Employment	Employment Maq {-i}	East-West Location	Domestic Inputs (%)	Technical Workers (%)
Textiles	Employment	0.175	-0.100	-0.319	-0.303	0.111	-0.153
n=15	Value added	0.017	-0.108	-0.339	-0.386	0.156	-0.733
r=0.4405							
Furniture	Employment	0.325	0.117	-0.022	-0.350	0.525	0.817
n=15	Value added	0.106	0.200	-0.053	-0.403	0.450	0.717
r=0.4405							
Transportation equipment	Employment	0.178	-0.022	-0.111	0.656	-0.047	-0.450
n=16	Value added	0.125	-0.008	-0.114	0.711	-0.139	-0.444
r=0.4258							
Electric/electronic goods	Employment	0.426	0.048	0.024	-0.185	0.497	0.307
n=14	Value added	0.310	-0.080	-0.098	-0.205	0.470	0.363
r=0.4574							
Electric/electronic components	Employment	-0.149	0.515	0.369	0.065	0.205	0.054
n=15	Value added	-0.143	0.539	0.438	0.235	0.116	0.155
r=0.4405							

Notes: n = number of cities that participate in the industry.
r = critical correlation coefficient for 90% significance level.
LQ = location quotient.
Employment Maq{-i}=Maquiladora employment exclusive of industry i.
East-West location refers to the relative geographic location of a city from East to West (see Figure B-1).
Source: Calculated from INEGI data.

of urbanization economies. Second, a positive, but statistically insignificant, correlation also existed between the LQ rank and the use of domestic inputs as a fraction of total inputs; on the other hand, correlation with respect to the use of technical workers was negative and significant when using value added LQs. Because both the percent of national inputs and of technical workers could be used as proxies for localization factors, we obtained no clear evidence of the presence of localization economies in the textile industry. Third, concentrations of textile maquiladoras were less likely to occur as the size of overall maquiladora employment in a city increases, implying that textile plants will locate in cities where maquiladora activity is incipient (e.g., interior Mexico). Finally, with the use of rank correlations, we also observed that textile firms tend to predominate in Western Mexico. To show this, we ranked each city according to their relative geographic location, such that the Eastern-most city in the sample, Matamoros, received a value of one, Reynosa, the closest city west of Matamoros, received a two, and so on. We then compared the East-West ranking of the cities with their LQ-ranking and computed correlation coefficients for each industry.

As mentioned above, the localization coefficient provides an index of the extent to which an industry is concentrated across the sample of cities. The localization coefficient for an industry only provides an index to be compared against those of other maquiladora industries; thus, it is only a relative measure. The localization coefficient for the textile industry was low relative to two other industries, furniture and transportation equipment (Table B.3, Appendix B), indicating that textile maquiladoras have a lesser tendency to concentrate relative to the other two industries.

Furniture

The furniture industry had the second largest growth rate of all maquiladora industries, an annual average of 68.0% from 1981 to 1989, only behind the transportation equipment industry. The industry increased its share of maquiladora employment from 2.5% in 1981 to 6.5% in 1990. Unfortunately, as mentioned earlier, shift-share figures for the furniture industry were inaccurate; thus, we cannot talk about the differential growth of the industries between border and non-border municipalities.

Four cities in the sample presented concentrations (as expressed by the employment LQ) of furniture maquiladoras: Tecate, Tijuana, Mexicali, and Ensenada; if the value added LQ is used, Juárez is included among the cities with concentrations of furniture maquiladoras. The four cities with the largest LQ were all located in the state of Baja California and account for 63.7% of the industry's national employment; Juárez accounts for an additional 24.5% of the industry's employment, so that 88.3% of all employment is concentrated in five cities. Furthermore, with the exception of Ensenada, four out of five cities are located along the border[5]; the employment of all other non-border cities in the sample adds up to only 1.3% of total employment in the industry. Thus, the furniture industry is highly concentrated in a small number of border cities. Relative to other industries in this study, the industry displayed the highest localization coefficient ($LC = 0.45$).

[5] Ensenada, however, is only 60 miles away from the border.

With the use of the rank correlation coefficients, we showed that concentration is correlated with the percent of domestic inputs used and with the fraction of technical workers in the labor force. As mentioned before, we could use domestic inputs and technical workers as proxies for localization factors. Nevertheless, pairwise correlation between LQ and other characteristics ignores correlation among those characteristics themselves; in particular, our use of technical workers or domestic inputs may present regional differences that will bias the correlation coefficients. For example, the maquiladora sector in Baja California employs more technical workers than it employs in other regions; therefore, since furniture maquiladoras are concentrated in Baja California, we will obtain a positive correlation between concentration and the use of technical workers. In order to account for correlations between variables, we must use econometric techniques similar to those used in Chapter 4. Finally, furniture maquiladoras also showed a positive correlation, yet insignificant, with population size, implying the existence of urbanization economies.

The fact that the furniture maquiladora industry has high location quotients in the state of Baja California parallels figures provided by Krugman (1991a) showing that the furniture industry in the United States concentrates in California. The possibility of having transborder concentrations of furniture firms would be an interesting research area, since we could show that maquiladoras do not concentrate in a locality due to agglomeration economies, but because of the industrial structure of the neighboring or closest region in the United States.

Transportation equipment

The transportation equipment maquiladora industry showed the highest growth rate in the maquiladora sector. From 1981 to 1989 employment increased by 723%, reaching a level of almost 99,000 workers by 1990. As a result, the industry became the second largest industry in the sector. The increases took place both in border and non-border municipalities, although the growth rate in the interior of Mexico was almost three times larger than in the border, 1556% *versus* 650%.

In terms of employment, eight cities presented concentrations of transportation equipment maquiladoras: Saltillo, Nuevo Laredo, Chihuahua, Monterrey, Matamoros, Acuña, Juárez, and Agua Prieta [See Table B.2, Appendix B]. They accounted for 78.2% of all employment in the industry. With the exception of Nuevo Laredo, three of the top four cities are located in the interior of Mexico, showing once again the extent to which transportation equipment maquiladoras have located in the interior of the country. Furthermore, cities in Western Mexico—Baja California and Sonora—present smaller LQs than the rest of the cities in the sample; thus, there is a strong correlation between the LQ size and the relative East-to-West location of the industry. This is interesting since transportation equipment plants in the United States predominate in the Midwest, relatively closer to North Eastern Mexico than to Baja California or Sonora.

In Saltillo, five out of seven maquiladoras are in the transportation equipment industry. This is of particular interest once we consider that the Saltillo area, which includes neighboring Ramos Arizpe, has an important concentration of non-maquiladora export manufacturing firms in the automobile industry. GM and Chrysler have one engine manufacturing plant each in the area; in addition, GM also assembles cars for the U.S. market. Nevertheless, it is not possible to identify any linkages between maquiladoras in Saltillo and automobile and engine manufacturers in the city from the data available; however, plants in Saltillo showed the highest percent of domestic inputs in the transportation equipment industry (3.2%) compared to plants in all other cities, with the exception of Mexicali (4.6%). In Nuevo Laredo, 16 out of 49 maquiladoras participate in the transportation equipment industry, while in Chihuahua only seven out of 55 do, but they show the highest average size of all firms in the industry.

Transportation equipment plant concentration showed insignificant correlation coefficients with regard to population or percent of domestic inputs; with respect to percent of technical workers, the correlation coefficient was negative and significant. Therefore, correlation figures suggest that urbanization and localization factors are negligible.

Electric and electronic goods

The electric and electronic goods industry is the third largest industry in the maquiladora sector; in 1990 it employed over 53,000 workers. The electric/electronic goods maquiladora industry grew at a slow rate relative to other industries in the 1981–1989 period, at a mere 11.1% per year. Again, the industry grew at a faster rate in the interior of Mexico than in border localities and the regional-shift component in non-border maquiladoras was large enough to offset the nation-wide decline in the industry's employment relative to other industries ($RS > |IM|$).

Fourteen cities in the sample contained firms in the electric/electronic goods industry. In addition, the sample accounted for only 50.6% of employment in the industry, implying that the industry may be scattered among smaller maquiladora centers. Moreover, only Juárez, where 26 out of 238 maquiladoras produced electric/electronic goods, showed a LQ greater than one (1.170); the industry in the rest of the cities was actually underrepresented (i.e., $LQ < 0.8$).[6] If the rest of the country is assumed to be another region, its location quotient in terms of employment would be equal to 4.4. This implies that the industry is overrepresented in the rest of the country and underrepresented in the 14 cities in the sample that participate in the industry. In terms of the number of firms at each location, 8 cities displayed LQs greater than one, while the LQ in terms of firms for the rest of the country equaled 0.871. Therefore, the cities in the sample a smaller firm size, in terms of the average number of workers, than the rest of the country. While the national size of the firm averaged 508 workers per firm, the average size in the sample was 380 workers per firm. As a consequence, the study's results might not be representative for the industry as a whole and should be taken with caution.

The LQ ranking of the cities showed significant correlation with population size and domestic input use; with regard to the percent of technical workers employed, the correlation coefficient was positive but statistically insignificant.

[6] Saltillo s value added and employment LQs greater than 1.2; nevertheless, there were no firms in the industry by the end of 1990. The apparent contradiction has to do with the fact that INEGI reports annual average data on employment and value added, but only reports the number of firms existing at the end of the year.

Hence, there is some evidence for the existence of urbanization and localization economies.

Electric and electronic components

The electric and electronic components industry is the largest industry in the maquiladora sector; it employed 127,047 workers in 1990, up from 42,791 in 1981. From 1981 to 1989 the industry grew below the national level, at a rate of 17.6% per year. Again, the industry grew faster in the interior of Mexico and, as a result, the regional shift component for non-border municipalities was positive. Nevertheless, the industry's decline in importance relative to other industries was large enough so as to offset the regional shift in employment in non-border cities ($RS < |IM|$).

The sample contained 15 cities that participated in the electric/electronic components industry. They comprised 95.7% of the industry's total employment; therefore, the results obtained in this study regarding the industry are highly representative of the industry as a whole. Five cities (Nogales, Reynosa, Matamoros, Chihuahua, and Juárez) presented LQs greater than 1.2; they account for almost 61% of the industry's national employment. Chihuahua was the only non-border municipality in the sample where the industry was concentrated. The industry was underrepresented or inexistent in the remaining five non-border municipalities included in the sample. Hence, electric/electronic components maquiladoras are more likely to locate along the border than in interior locations.

The industry only displayed significant rank-correlation coefficients with respect to the city's maquiladora employment. The correlation coefficient was positive, implying perhaps that firms in the industry locate in cities where the maquiladora sector is well established; alternatively, since the industry accounts for a large percent of total maquiladora employment in the country (26.7%), a high correlation coefficient may exist simply because a high fraction of the industry's employment in a city considerably increases the city's overall maquiladora employment. Nevertheless, the correlation coefficient with respect to maquiladora employment *exclusive* of the electric/electronic components industry is positive and

Table 3.5: Specialization coefficients

Municipality	Specialization coefficients in terms of: Employment	Value added	Highest-LQ Industry	Highest Employment Industry
Torreon-Gomez Palacio-Lerdo	0.814	0.736	Textiles	Textiles
Saltillo	0.590	0.566	Transportation	Transportation
Tecate	0.509	0.485	Furniture	Furniture
Hermosillo	0.504	0.494	Textiles	Textiles
Monterrey (Metropolitan area)	0.482	0.445	Transportation	Transportation
Piedras Negras	0.477	0.447	Textiles	Textiles
Nuevo Laredo	0.452	0.464	Transportation	Transportation
Ensenada	0.445	0.614	Furniture	E/E components
Nogales	0.371	0.380	E/E components	E/E components
Matamoros	0.344	0.381	Transport, ee comp.	E/E components
Chihuahua	0.324	0.337	Transportation	Transportation
Acuna	0.313	0.294	Transportation	Transportation
Reynosa	0.286	0.252	E/E components	E/E components
Tijuana	0.280	0.346	Furniture	E/E components
Mexicali	0.238	0.393	Furniture, textiles	E/E components
Agua Prieta	0.179	0.155	Transportation	E/E components
Juarez	0.154	0.145	Transportation	E/E components
Rank correlation vis-a-vis:				
Maquiladora employment rank	-0.617	-0.620		
Population rank	-0.017	0.015		
Critical correlation coefficient = 0.482 (95% significance level)				

Source: Calculated from INEGI data.

large, albeit statistically insignificant.

With respect to population size, industrial concentration showed a negative yet insignificant correlation coefficient, hinting at the presence of urbanization diseconomies. With regard to localization factors, the industry had positive correlation coefficients with respect to the percent use of domestic inputs and technical workers, but the coefficients were insignificant.

3.3.3 Regional specialization

So far, we have presented figures that show where maquiladora industrial clusters exist, focusing on five industries and showing in which cities those industries are overrepresented. Now, we look at the extent to which the industrial distribution of the maquiladora in a given city diverges from the nation's distribution. To this effect, specialization coefficients for the 17 cities in the sample were computed.

Table 3.5 presents the specialization coefficients for each city and ranks all cities from highest-to-lowest coefficient. Specialization coefficients ranged from 0.814 in Torreón, where textile maquiladoras predominate, to 0.154 in Juárez, with high LQs in the transportation equipment and the electric/electronic components industries.

We used the specialization coefficients to study the way in which regional specialization varied with respect to population and size of the maquiladora sector. We computed rank correlation coefficients between the specialization coefficient and population and maquiladora sector sizes in each city. Population size appeared to be uncorrelated to the degree of specialization of a city. In contrast, we observed that the degree of specialization of a locality decreases the larger the size of the maquiladora sector in that locality is; this correlation is statistically significant at the 97.5% significance level (Table 3.5). We can pose several hypothesis to explain such inverse correlation.

A first hypothesis is that the industrial mix of a given city will converge toward the national average mix as the size of the maquiladora sector in the city increases. Over time, the largest maquiladora employment centers have been able to attract a more diverse set of industries. Presumably, other cities will also attract different industries once their absolute share of maquiladora employment increases, so that they become less specialized through time. Second, cities in the interior tend to specialize more than cities on the border, and since maquiladora employment is smaller in non-border maquiladoras, there is a negative correlation between population and maquiladora size. In the sample used, four interior cities, (Torreón, Saltillo, Hermosillo, and Monterrey) were among the five cities with the highest specialization coefficients, along with Tecate, a border town. Maquiladoras in the interior of Mexico usually acquire a larger proportion of their inputs from Mexican suppliers, thus they might be influenced by localization factors and will show a greater tendency to concentrate in space. In contrast, maquiladoras in border localities will be less influenced by localization economies, at least by those arising from the availability of specialized material inputs, since those maquiladoras import most of their inputs from the United States; however, maquiladoras in border cities might still be affected by the localization economies arising from the availability of specific labor skills. Third, since the maquiladora sector is still largely concentrated in a few cities, the national average industrial mix will resemble that of the largest maquiladora centers in Mexico (Juárez, Tijuana, Matamoros, etc.) Furthermore, since the specialization coefficient compares national to local figures, the larger the size of the locality, the closer its industrial mix will be to the nation's mix. As a result, specialization decreases with size of the maquiladora sector. Unfortunately, testing the above hypotheses is beyond the scope of this thesis.

3.4 Summary

In determining the extent to which industrial concentration in the maquiladora sector occurs, we looked at the spatial profile of the maquiladora sector in Mexico. We examined data for 17 urban areas and five maquiladora industries using a series of techniques widely used in regional economic analysis. The techniques included the location quotient, the specialization and localization coefficients, the locational Gini coefficient, and shift-share analysis. We compared the degree of concentration of an industry in each city—as defined by the location quotient—to specific characteristics of the industry and the city by means of rank-correlation coefficients in order to identify factors that may influence an industry's concentration in a city relative to that of other cities. We used population size as a proxy for the presence of factors causing urbanization economies; similarly, we used the percent of domestic inputs purchased by an industry and the percentage of technical workers employed as proxies for localization factors.

Two industries, furniture and electric/electronic goods, showed positive rank-correlation coefficients *vis-a-vis* domestic input use and technical employment, implying that above average concentrations of maquiladoras might be explained by localization economies. In addition, the electric/electronic component industry also showed positive correlation coefficients with localization factors, though the coefficients were statistically insignificant. On the other hand, transportation equipment maquiladoras presented negative coefficients, although correlation with the domestic input use variable was insignificant. Evidence for the textile industry was inconclusive. The degree of maquiladora concentration was positively correlated to population size in all industries, with the exception of the the electric and electronic components industry. However, the correlation coefficient was only significant in the electric/electronic goods industry; the coefficient was statistically insignificant in the remaining four industries.

Our use of rank correlation coefficients provided insights into some of the factors that may lead to industrial concentration. Nonetheless, the technique is flawed in that it ignores pairwise correlation among the variables against which location quotients are compared. In the next chapter, we apply a multivariate econometric model that takes into consideration pairwise correlation. Furthermore, we constructed the model explicitly to account for urbanization and localization factors and to provide clear evidence for or against localization economies.

Chapter 4

Industrial Concentration and its Determinants

In this chapter, we present an econometric model to study the determinants of industrial concentration. The model includes variables to account for the presence of urbanization and localization economies in five maquiladora industries. Even though the model is incapable of providing definitive evidence for or against urbanization and localization economies, it does in fact point at industries were agglomeration economies may be at work. Hence, the model is useful in indicating where future research should focus.

The results obtained show that localization and urbanization economies and diseconomies exist in some maquiladora industries.

4.1 Model

The formulation of the model presented in this section draws extensively from the works of Moomaw (1988) and Henderson (1986); to a lesser extent, it also considers the work of Nakamura (1985). The models presented by these authors typically consider some production function that includes the inputs used in the production process (e.g., labor and capital) and a term to account for factors external to the firm, but which may influence its output.

For any firm in a given industry and city, Moomaw (1988) makes use of a Cobb-Douglas (CD) production function with constant-returns to scale (CRS) of the form

$$q_i = a l_i^d k_i^{1-d} \phi(N, V), \tag{4.1}$$

where q_i is firm i's output in a given period; l_i and k_i are labor and capital inputs; $\phi(N, V)$ is a function of external factors N, city size, and V, industry size; and a and d are parameters. City size is expressed in terms of inhabitants; it may also be given by the city's gross product, but such a figure is usually hard to obtain. Industry size can be expressed either in terms of employment or value-added; both variables were considered in this study.

The cost minimization first-order condition for any given output implies

$$\frac{\partial q_i}{\partial l_i} = w = a d l_i^{d-1} k_i^{1-d} \phi(N, V), \tag{4.2}$$

where w is the wage rate. By rearranging Equation (4.2) and summing over all firms in the industry, as permitted by the CRS assumption, we obtain the industry's labor demand function in each city (Moomaw, 1988); that is,

$$w \sum_{i=1}^{n} l_i^{1-d} = a d \phi(N, V) \sum_{i=1}^{n} k_i^{1-d}, \tag{4.3}$$

such that

$$L = \left[a d \phi(N, V) w^{-1} \right]^{\frac{1}{1-d}} K. \tag{4.4}$$

By rearranging Equation (4.4) and taking (natural) logarithms, we obtain regression Equation (4.5),

$$\log\left(\frac{L}{K}\right) = \left(\frac{1}{1-d}\right) \log(ad) + \left(\frac{1}{1-d}\right) \log \phi(N, V) + \left(\frac{-1}{1-d}\right) \log w. \tag{4.5}$$

In order to estimate Equation (4.5), Moomaw (1988) uses an external factor function of the form $\phi(N, V) = N^b V^c$,and measures industry size by value added in the city ($V = \sum_i q_i = Q$). Thus, he estimates the following equation:

$$\log\left(\frac{L}{K}\right) = \left(\frac{1}{1-d}\right)\log(ad) + \left(\frac{b}{1-d}\right)\log N + \left(\frac{c}{1-d}\right)\log Q + \left(\frac{-1}{1-d}\right)\log w, \quad (4.6)$$

where value added minus payroll is used as a proxy for K. As indicated by Moomaw (1988, p. 154), K is subject to measurement errors; Moomaw argues that using K as part of the dependent variable minimizes the negative effect of flawed measures of K.

In this thesis, we estimated several variants of Equation (4.5) using different functional forms for $\phi(\cdot)$. In all instances the wage coefficient was positive (and significant in three industries), implying that, as wages increase across cities, labor is substituted for capital. We may consider that a high labor-demand by the maquiladora sector in a city bids up wages and that, thus, the positive wage coefficient captures such effect. Nevertheless, the pairwise correlation coefficient between employment and wages is negative in all industries. Furthermore, the dependent variable in Equation (4.5) represents the substitution of labor for capital—and not the amount of labor employed by an industry—as a function of wages. Recalling the Heckscher-Ohlin model (section 2.1.1), we would expect that more capital would be used instead of labor as wages increase; that is, we would expect a negative wage coefficient. Inefficient measures of K might have been responsible for the wage coefficient's anomalous sign. In addition, the special nature of maquiladora production possibly exarcebated the problem of using K. Maquiladoras' main input is labor; other factors of production play only a minor role. Thus, increases in the wage rate will not lead to significant substitution of other inputs for labor in the short run. Therefore, an alternative regression equation is necessary.

Moomaw (1988) derives another model based on the constant-elasticity of substitution (CES) production function. The CES production function leads to a labor demand function independent of the capital variable K. In its general form, the CES production for firm i in a given industry is given by

$$q_i = j\left[rl_i^{-s} + (1-r)\,k_i^{-s}\right]^{\frac{-1}{s}}. \tag{4.7}$$

Again, cost minimization requires

$$\frac{\partial q_i}{\partial l_i} = w = jr\left[rl_i^{-s} + (1-r)\,k_i^{-s}\right]^{\frac{-(1+s)}{s}} l_i^{-(1+s)}. \tag{4.8}$$

Rearranging,

$$l_i = (jr)^{\frac{1}{1+s}}\left[rl_i^{-s} + (1-r)\,k_i^{-s}\right]^{\frac{-1}{s}} w^{\frac{-1}{(1+s)}} \tag{4.9}$$

Since $j^{1/(1+s)} = j \cdot j^{-s/(1+s)}$, Equations (4.7) and (4.9) can be combined to produce

$$l_i = j^{\frac{-s}{1+s}} \cdot r^{\frac{1}{1+s}} \cdot w^{\frac{-1}{(1+s)}} \cdot q_i. \tag{4.10}$$

Summing over all n firms in the industry and making use of the CRS nature of the CES function, the labor-demand function for the industry is obtained:

$$L = j^{\frac{-s}{1+s}} \cdot r^{\frac{1}{1+s}} \cdot w^{\frac{-1}{(1+s)}} \cdot Q. \tag{4.11}$$

Now, in order to introduce external factors into the labor-demand function (Equation (4.11)), let $j = j' \cdot \phi(N, V)$, where $\phi(\cdot)$ is a function similar to that used in the CD function (Equation (4.1), page 64). Hence, Equation (4.11) can be rewritten as

$$L = j'^{\frac{-s}{1+s}} \cdot r^{\frac{1}{1+s}} \cdot w^{\frac{-1}{(1+s)}} \cdot [\phi(N, V)]^{\frac{-s}{1+s}} \cdot Q, \tag{4.12}$$

and its logarithmic form is

$$\log L = \alpha + \beta_1 \log w + \left(\frac{-s}{1+s}\right) \log \phi(N, V) + \log Q, \tag{4.13}$$

where $\alpha = \left(\frac{-s}{1+s}\right)\log j' + \left(\frac{1}{1+s}\right)\log r$ and $\beta_1 = \left(\frac{-1}{1+s}\right)$.

Given that there is no theoretically-based functional form for $\phi(\cdot)$, we experimented with four different functional forms: (i) $\phi_1(N, V) = N^b \exp\frac{-c}{V}$; (ii)

$\phi_2(N,V) = \exp^{\frac{-b}{N}+\frac{-c}{V}}$; (iii) $\phi_3(N,V) = N^b V^c$; and (iv) $\phi_4(N,V) = \exp^{\frac{-b}{N}} V^c$. Using the four functional forms and two alternative measures for industry size V—value added (Q) and employment (L)—we obtained five regression models (Appendix C). Using cross-section data for each industry, the five models test for urbanization and localization coefficients in each industry. The use of different functional forms yields different combinations of the urbanization and localization variables. Models A and B use a log-inverse and inverse-inverse combination of population and employment, respectively; Models C, D, and E use log-log, log-inverse, and inverse-log combinations of population and value added in the industry, respectively. Ideally, each model should provide similar qualitative information; in practice, however, we found that, while a model may yield significant estimates, other model's estimates may be meaningless or even contradictory. Thus, rather than choosing one particular model, we use all five models and derive conclusions based on those that present significant estimates. Regression results are reported in Table C.1.

In order to account for potential correlation of some of the independent variables and the error term, we estimated the five regression equations by creating instruments for the wage level and value added in the industry. After experimenting with several combinations of geographic and industry-specific characteristics, we chose those variables that could account for a high percentage of the observed wages and value added; that is, those variables that yielded high R^2 for the first-stage least-squares regressions. In this manner, the instrumental variables were regional dummies (border/non-border, east/central/western Mexico), the logarithm of worker productivity (value added per worker) in the industry in each city, and the proportion of employees (i.e., white-collar workers) with respect to total employment as an index for the composition of the labor force. In addition, we included the exogenous population and industry-size variables used in the second-stage regression to create the instruments. All of these variables were capable of explaining a high percentage of the observed wages and value added; that is, the R^2 for the first-stage least-squares regressions were high (close to one).

In computing the regression equations, we encountered two problems. First, the sample of cities used was very small, and, as a result, the equations' degrees of freedom ranged from 10 to 12. Although many of the regressions' coefficients were significant at the 5% level, others were only significant at the 10% level, while others were insignificant (Table C.1, Appendix C). Second, in addition to low significance levels, high R^2s were observed in all cases, suggesting the presence of multicollinearity in the model (Ramanathan, 1989, p. 233). In some cases multicollinearity appeared as the result of high correlation coefficients among some of the independent variables. Unfortunately, since the models were structurally derived, it was impossible to dispense with some of the correlated variables to solve the problem of multicollinearity. Multicollinearity may also be solved by increasing the sample size; again, such an alternative was not readily available since we had already included the largest maquiladora centers in Mexico in the sample and other cities that we had not included in the study would present relatively small industry sizes.

Multicollinearity among explanatory variables increases the standard error of the regression coefficients and reduces the coefficients' t-statistics (Pindyck and Rubinfeld, 1991; Ramanathan, 1989). As a result, the regression coefficient tend to be less significant, or insignificant altogether. Nevertheless, they remain unbiased, efficient, and consistent, that is, they are still BLUE (best linear unbiased estimators), and therefore, we can still use t-statistics for hypothesis-testing (Ramanathan, 1989, p. 232–233). Thus, Ramanathan (1989, p. 234) concludes that, "if the regression coefficients are significant and have meaningful signs and magnitudes, one need not be concerned about multicollinearity."

4.2 Results

Despite the small sample of cities and the associated multicollinearity of the model, several of the regression coefficients we obtained and report in Table C.1 (Appendix C) were significant at the 5% and 10% level. Thus, the results provide us with qualitative information about the nature of agglomeration economies—either in the form of localization or urbanization economies. We discuss the existence or non-existence of external economies of agglomeration by analyzing the specific experience of five maquiladora industries and comparing the regression results with those presented in Chapter 3.

Textiles

For each of the five regression models, we obtained acceptable results for the textile industry. First, all of them presented negative and significant wage coefficients, implying that the demand for labor decreases as the wage level increases. Furthermore, the wage coefficient was different from -1 and, thus, the localization and urbanization parameters (c and b, respectively) are identifiable, provided the corresponding coefficients are significant. Second, at least two coefficients were statistically significant at the 5% level, with another coefficient being significant at the 10% level. Third, all models presented high R^2's. Although a high R^2 may indicate the presence of multicollinearity, the existence of significant coefficients allows us to test hypotheses regarding the existence of localization and urbanization economies.

Maquiladoras in the textile industry showed signs of industrial localization. Two regression models (A and B) presented significant localization parameters ($c > 0$) at the 5% level; the remaining three models presented localization parameters that were statistically insignificant. On the other hand, the evidence for urbanization economies or diseconomies was inconclusive. Two models (C and D) showed positive urbanization parameters significant at the 5% and 10% levels, while another model (E) indicated urbanization diseconomies ($b < 0$) significant at the 5% level. As mentioned earlier, although the five different model variants should ideally yield the same results, data imperfections and a small sample may result in contradictory regression coefficients.

Furniture

Results for the furniture industry were not as auspicious as those for the textile industry. Student t-statistics tended to be lower, albeit significant at the 10% and 5% levels. More importantly, the wage coefficients were statistically equal to -1 in three models (A, B, and C), thus creating an identification problem.[1] Therefore, we only look at results from models D and E.

Both models D and E showed evidence of urbanization economies at the 10% level of significance. This contrasts with our results from Chapter 3, where population size and industrial concentration were uncorrelated. On the other hand, whereas in Chapter 3 we observed a positive correlation between both percent-input use and technical-employment and industrial concentration, econometric results showed no evidence of localization economies. As we mentioned earlier, the use of rank-correlation coefficients between industrial concentration and city and industry characteristics may hide correlation among some of those characteristics. Accordingly, econometric results may contradict rank-correlation results, because the former do take into consideration correlation among independent variables.

Transportation equipment

All five models produced negative wage coefficients that are statistically equal to zero ($\hat{\beta}_1 = 0$). A wage coefficient equal to zero may indicate that the demand for labor remains indifferent to wage differences *across Mexican cities*. This does not mean, however, that a firm in the industry has an inelastic demand for labor, but, rather, that the industry is not concentrated in low-wage cities. On the other hand, with the exception of one regression coefficient (logarithm of value-added), the t-statistics for all coefficients in models A, B, and C, were insignificant. Models D and E performed better, with significant coefficients at the 5% and 10% levels. Therefore, we considered only models D and E in analyzing the transportation equipment industry.

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[1] See Appendix C, section C.1.1

According to the regression results for models D and E, transportation equipment maquiladoras exhibited a marked tendency to agglomerate due to localization economies. We have difficulty explaining the positive localization parameters by looking at the input-use and labor-skill characteristics of the transportation equipment industry. Transportation equipment maquiladoras do not stand out as intensive users of Mexican inputs and, consequently, of inputs supplied by producers located in the city where the maquiladora plant locates. Furthermore, the relative size of the transportation industry in a given city does not seem correlated with the use of domestic inputs (Table 3.4). Also, the use of technical workers, assumed here to be a proxy of the skill-level of the work force, was negatively correlated to LQ rank—i.e., to the relative size of the industry (Table 3.4). We should note that the percentage of technical labor does not capture other labor skills that may act as localization factors. For example, all workers, not only technical employees, may possess the labor-skills required by the industry. A city's blue-collar labor-force may possess a work ethic more amenable to maquiladora production as the size of the maquiladora sector increases. Industries in which labor-training is more extensive and costly may then benefit from access to workers who are accustomed maquiladora activities.[2] Therefore, if localization economies indeed exist, future research should explore why transportation equipment (and other industries) maquiladoras benefit from clustering in a city.

In addition, model E showed that urbanization economies are important in the industry. The existence of urbanization economies contradicts the findings presented in Table 3.4, which shows a negligible correlation between population-rank and LQ-rank.

Electric and electronic goods

All five regression models exhibited wage regression coefficients equal to -1. As a result, we are unable to detect the sign and magnitude the urbanization and

[2]On the other hand, large concentrations of maquiladora employment may encourage labor turnover as a higher demand for labor decreases the search cost for jobs.

localization coefficients—i.e., all models are subject to identification problems. The sample of cities with firms in the electric/electronic goods industry was the smallest of all five five industries we have considered, so that might have explained the poor results obtained in the model. Also, the industry was not well represented in the sample relative to the national employment level. For instance, as we saw before, only Juarez presents a concentration of firms in the area above the national average.

In Chapter 3 we saw that there is a large correlation domestic input use and the LQ-rank (Table 3.4); moreover, the LQ rank-correlation with respect to technical employment was positive but statistically insignificant. With respect to population size, there was again a positive correlation with the LQ in the sample of cities. Unfortunately, we could not corroborate or reject those results. We need follow up studies in order to understand whether input availability plays a role in driving industrial localization and to assess the importance of labor skills and urbanization economies. Future studies should examine whether local suppliers exist and the quality of local workers—engineers, technicians, managers—among other potential localization and urbanization factors.

Electric and electronic components

Similar to the case of the electric/electronic goods industry, the electric and electronic components industry was affected by the under-identification problem; two of the models (D and E), however, presented a wage coefficient greater than -1, but smaller than zero. Furthermore, models D and E displayed higher t-statistics than the other three models; thus, we preferred models D and E over the remaining models.

Models D and E pointed to the existence of localization economies at the 5% level of significance. Although, in Table 3.4, we observe a positive correlation between concentration and localization factors, the correlation is not significant. Thus, further studies are needed to determine whether input-use or skilled-labor availability, or both, account for the localization economies in the electric/electronic components industry.

Table 4.1: Relevant agglomeration factors in five maquiladora industries

Industry	Localization Economies	Urbanization Economies
Textiles	Economies	Inconclusive
Fumiture	Negligible	Economies
Transportation equipment	Economies	Economies
Electric and electronic goods	Faulty model	
Electric and electronic components	Economies	Negligible

Source: Calculated from INEGI data.

The evidence for urbanization economies was negligible in models D and E, implying that electric/electronic component maquiladoras are insensitive to city size. Moreover, our results from Chapter 3 show negative correlation, albeit statistically insignificant, between population size and relative concentration. Although we cannot make any definitive statements from statistically insignificant results, the rank-correlation coefficient's negative sign would hint at the existence of urbanization diseconomies.

4.3 Summary

In this chapter, we used an econometric model that accounts for the existence of external economies of localization and urbanization. We posed several variants of the model according to different functional specifications for external factors and run each variant for five different maquiladora industries in 14–16 metropolitan areas.

The regression results—summarized in Table 4.1—suggest that localization economies are important in at least three of the industries: textiles, transportation equipment, and electric/electronic components. In contrast, evidence for the furniture industry seemed negligible. Urbanization economies appeared to be significant for the furniture and transportation equipment industries; in contrast, the electric/electronic components and textile industries seemed unaffected by city size. Regression results were not applicable to the electric/electronic goods industry.

Nonetheless, we may challenge the above results because the regression models and the data we used to compute them had several deficiencies. First, the models were affected by multicollinearity among the independent variables. Second, the sample-size was fairly small ranging from 14 to 16 cities; consequently, the number of degrees of freedom was small. Third, our proxies for localization and urbanization factors might have been imperfect. Finally, some of the model-variants yielded contradictory results. As a result, we had difficulty making any definite conclusions about the presence, or lack thereof, of localization and urbanization economies, or, if they indeed exist, why they may arise.

The results we obtained in this chapter, however, shed light on which industries may potentially be exhibiting a tendency to agglomerate due to the existence of localization economies. In order to determine what the driving factors behind localization are—or whether localization is occurring at all—further studies are needed. By focusing on the three industries that appear to be influenced by localization economies and that we have identified in this study, we may learn more about the relationship between the maquiladora sector and its host communities. Moreover, in future studies, we should not only look at aggregate industrial data, as we have done, but we must also consider more detailed data for the industry, as well as firm-specific data. In the next chapter, we present some of the issues that a study of the maquiladora sector should consider.

Chapter 5

Conclusions

5.1 Summary

In this thesis, we explored the way in which *maquiladoras*—or offshore assembly plants—relate to the economies of those communities where they locate. We focused on above-average concentrations of maquiladora plants in the same industry and tested for *localization economies* as the driving factor behind industrial concentration.

We deemed localization economies important because they would indicate that some maquiladora industries have established *linkages* to their host communities. Those linkages could take the form of *backward* linkages—i.e., the purchase of local material inputs—or the need for specialized labor skills by the industry. Linkages help spur economic growth because maquiladora benefits are not restricted to direct employment creation, but foster employment growth in other industries as well. The existence of linkages also decreases the footloose character of assembly production and prevents maquiladoras from migrating to lower-wage communities. This is particularly important given changes in the global character of industrial production—automation, flexible production schemes—that threaten to shift offshore assembly production back to the industrialized world.

We analyzed data for five maquiladora industries through the use of econometric models that accounted for external economies of agglomeration. We included localization and urbanization economies into the models as potential agglomerative forces. The former imply that, as the size of the industry increases, the average costs of any firm in it fall; the latter mean that any firm benefits from locating in large cities where services and inputs are readily available to all industries. As argued above, we paid particular attention to the existence of localization economies.

There is some evidence for the presence of localization economies in three industries (*textiles, transportation equipment,* and *electric and electronic components*). In contrast, evidence of localization economies in the *furniture* industry was negligible, while results for the *electric and electronic goods* industry did not allow us to identify localization economies or diseconomies. On the other hand, urbanization economies seemed significant for the furniture and transportation equipment industry, while they were unimportant in the electric/electronic components industry. Again, results for the electric/electronic goods industry were not meaningful.

While the econometric models we used provided us with some indication of which factors drive industrial concentration, the models were affected by several problems—multicollinearity, a small sample-size, low t-statistics. Furthermore, the models were not capable of distinguishing what determinants of localization economies. To bridge such shortcoming of the models, we studied the way in which industry and city characteristics varied with the degree of industrial concentration, as measured by the use of location quotients. To that effect, we computed rank-correlation coefficients and tested for statistical significance. Unfortunately, several of those coefficients were statistically insignificant. Moreover, they sometimes contradicted our econometric results, preventing us from identifying what the factors behind industrial concentration and localization are. Hence, we end up by analyzing what research steps would be needed to understand better why maquiladoras may tend to cluster and what the implication of such clustering may be for local economies.

5.2 Policy implications

Fostering an increase in the overall level of maquiladora production in a city helps create employment opportunities for the city's population. Nevertheless, if industries are attracted to a locality solely because of a large supply of inexpensive labor, maquiladoras would find it easy to move elsewhere if wages increased or if technological and organizational changes in the industry made unskilled labor dispensable. In contrast, local governments may find it profitable to promote local economic development by targeting industries with a tendency to localize.

As stated earlier, localization offsets footlooseness. The existence of localization economies in some maquiladora industries suggests that it is possible to attract maquiladora plants to a city and to create maquiladora employment based on factors other than low wages. Therefore, a rise in wages will not be paralleled by relocation to lower-wage sites; instead, the decline in average costs that arises from the availability of local inputs or specialized skills—the factors behind localization—may be large enough so as to compensate for wage increases. Furthermore, even if an industry is unaffected by localization economies, the existence of above-average industrial concentrations could be exploited, to the community's benefit, by providing incentives for the creation of local suppliers. Hence, knowledge about which industries present a tendency to localize is not enough. Information is also needed on the relationship between the different maquiladora industries and their host communities.

The need to understand the relationship that exists between maquiladoras and their host communities is important for at least two reasons. First, the unintegrated character of maquiladora production has prevented it from becoming a springboard for further economic development. Integration in this context is understood as the existence of strong linkages between the maquiladora sector and the host communities in the form of increased local sourcing of material inputs, transfer of technology that otherwise would not be available to the community, and labor skill upgrading as maquiladoras implement labor-training programs. Hence, it is important to evaluate which industries have the largest potential to integrate and which mechanisms and strategies are available to local policy makers to foster integration.

A second reason to study the relationship between local economies and maquiladora production is to understand how assembly plants are adapting to changes in the technological and organizational structure of global industrial production. If maquiladoras fail to adapt to those changes, they may remain largely incapable of spurring long-term economic growth in their host communities. However, the introduction of new production techniques in maquiladora production does not guarantee such growth; indeed, they may remain an export enclave.

Nonetheless, it was not within the scope of the thesis to provide a deeper understanding of industry and city characteristics that favor localization. In order to shed light on the factors that may foster industrial growth and concentration in a given city, more data and studies are needed. Thus, we conclude by presenting an agenda for further research.

5.3 Agenda for further research

We consider two future research directions. First, a study on how the maquiladora sector and industries in it are related or *linked* to the local economy of a particular city. In the study, we would try to identify the extent to which *forward* and *backward linkages* between the maquiladora sector and the local economy have been established, and the kinds of structural barriers that prevent stronger linkages and further integration to the community. In addition, we would look at the kind of initiatives and programs that have been put, or are, in place to foster the creation of linkages. Second, we would look at how maquiladoras are adapting to changes in the organizational and technological structure of global production. Here, we would consider the adoption of new technologies and interfirm cooperation arrangements and, if their adoption is indeed occurring, their effect on host communities. The research agenda we present considers elements of both approaches, but places a greater emphasis on the study of maquiladoras and local linkages.

How can we study the implications of global changes in industrial production on maquiladora communities? How could economic growth be promoted? An answer to these questions requires an inquiry into the way in which maquiladoras at the local level interact with each other, with local industry, with the local labor force—i.e., the people of the community—and with local institutions.

In studying the constraints on greater integration and of the implications of new trends in global production, we suggest looking at the following:

1. *Firm-specific characteristics:* It is necessary to know how the age of different plants, their size, and other characteristics of the firm influence its use of new technologies, labor-training programs, cooperative arrangements with other firms, etc. Some of the questions that we propose answering are:

   (a) Is automated technology being used?
   (b) Which flexible production technologies and techniques are being used (just-in-time inventorying; statistical control processing)?
   (c) What type of labor-training programs are being implemented?
   (d) How does the use of new technologies affect firms' integration to the local economy?
   (e) What kind of inputs are purchased?
   (f) How do input purchases vary with firm characteristics?

2. *Industry-specific characteristics:* Industries that make up the maquiladora sector present different degrees of integration to the local communities. They may purchase different amounts of inputs from domestic suppliers. They may also require different degrees and kinds of labor skills; for instance, textile maquiladoras may employ largely unskilled workers that can be trained rapidly, while some, but by no means all, electronics maquiladoras require larger numbers of engineers and technicians. Although differences indeed exist between firms within the same industry, by focusing on specific industries—rather than on the maquiladora sector as a whole—we may

identify those industries that have established, or those that present a greater potential to establish, linkages to their host communities.

For an industry analysis, we must consider the way in which firms in the industry interact with each other; that is, the type of interfirm transactions and forms of cooperation, the existence of subcontracting networks in the locality, etc. In addition, we must consider how different maquiladora industries relate to each other and to the local industrial base.

3. *Locational factors:* Of particular relevance to the study is the identification of locational attributes specific to each community that attract a given kind of maquiladora industry. Doeringer and Terkla (1990) use the term *invisible factors* to refer to city-specific characteristics—other than input cost and availability—that influence a firm's location choice. Invisible factors include labor-force quality, labor-management relations, and interfirm cooperative arrangements (Doeringer and Terkla, 1990, p. 492). They argue that development efforts should exploit the existence of those factors as a basis for local economic development. Therefore, the following questions should be answered:

   (a) Does the existence of other plants in the same industry influence the location decision of a maquiladora?
   (b) Are local labor skills a determining locational factor?
   (c) Besides labor availability, which factors influence a firm's location decision?

4. *Government policies:* Local governments should explore which kind of structural and institutional constraints have prevented maquiladoras from purchasing a larger proportion of their inputs from local firms.

   (a) What factors prevent maquiladoras from purchasing more inputs?
   (b) Are there any programs in place to increase local input use?
   (c) Why have previous efforts to integrate the maquiladora into the local economy failed?

(d) Do firms have any suggestions as to which kind of programs could increase integration into the local economy?

Future policy regarding maquiladora production in Mexico should be based on a systematic analysis of the factors mentioned above. An indiscriminate policy to foster maquiladora employment creation is less promising than a concerted strategy to ground global capital to the local economies of Mexican host communities, i.e., to offset footlooseness by creating local linkages. If the maquiladora sector is successfully integrated into the Mexican economy—both at the local and national level—maquiladoras will propel and multiply employment and economic growth. Otherwise, maquiladora communities will continue to suffer the social costs of assembly production, while foregoing long-lasting economic development.

Appendix A

Maquiladora industries

In this appendix, we present a list of maquiladora industrial categories, as used by INEGI. The industries we analyzed in this study are indicated by an asterisk.

1. Selection, preparation, packing, and canning of food.
2. Cloth and other textile products assembly.*
3. Shoe and leather industry.
4. Assembly of furniture and its accessories and other wood and metal products.*
5. Chemical products.
6. Construction, re-construction, and assembly of transport equipment and its accessories.*
7. Assembly and repair of tools, equipment, and their parts, except electric.
8. Assembly of electric and electronic machinery, equipment, apparatus, and goods.*
9. Electric and electronic materials and accessories.*
10. Assembly of toys and sports goods.
11. Other manufacturing industries.
12. Services.

Appendix B

Geographic profile

We applied the techniques presented in Chapter 3 to data on the regional characteristics of the maquiladora sector in a sample of 17 Mexican cities (see Figure B-1). In Table B.1, we present information pertaining to each industry in the sample of cities. In addition, in Table B.2 in this appendix, we report the location quotients for five maquiladora industries, ranking cities from highest to lowest location quotient. We also report the industry's employment share at each locality. Finally, in Table B.3, we show the localization coefficients for each of the five industries.

Figure B-1: Cities considered in the study

Table B.1: Maquiladora sector's regional characteristics (1990 figures)

Municipality Industry	Number of firms	Number of workers	Value added in Mexico	% domestic inputs (total)	% domestic inputs (VA)	% technical workers
National total	1,938	475,762	10,127,911,750.0	1.58	3.68	0.11
Food	46	7,966	264,120,361.0	20.80	9.51	6.86
Textiles	289	42,036	566,591,261.0	0.87	1.46	10.81
Shoe and leather	51	7,318	126,293,567.0	2.38	5.39	9.62
Furniture	265	30,711	565,368,115.0	3.38	6.34	9.42
Chemical products	88	6,885	161,794,213.0	10.17	5.66	7.49
Transportation equipment	158	98,922	2,555,515,475.0	0.92	2.37	11.99
Tools and equipment	34	4,960	125,481,070.0	1.36	3.72	10.81
Electric/electronic goods	105	53,359	1,183,729,776.0	1.35	4.59	14.11
Electric/electronic componei	396	127,047	2,626,879,298.0	0.74	1.91	14.07
Toys	29	10,698	254,021,865.0	0.32	0.73	11.80
Other industries	373	65,867	1,406,560,672.0	4.42	7.75	9.73
Services	86	19,995	291,556,077.0	2.33	2.32	6.20
Acuna	39	14,276	196,990,568.0	0.41	1.76	11.76
Food	--	--	--	--	--	--
Textiles	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Shoe and leather	3	1,078	13,680,745.0	1.13	4.83	17.63
Furniture	5	272	5,467,583.0	0.16	0.51	9.56
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	3	4,161	60,241,755.0	0.00	0.00	11.44
Tools and equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componei	8	3,759	57,214,440.0	0.02	0.12	14.98
Toys	3	1,064	14,200,984.0	0.04	0.12	9.40
Other industries	12	1,670	21,236,238	0.90	2.43	7.84
Services	5	2,272	24,948,823.0	0.71	0.07	8.27
Agua Prieta	22	5,738	82,088,071	0.19	0.20	22.87
Food	--	--	--	--	--	--
Textiles	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Shoe and leather	--	--	--	--	--	--
Furniture	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Tools and equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componei	8	1,793	32,009,147	0.45	0.52	23.20
Toys	--	--	--	--	--	--
Other industries	14	3,945	50,078,924	0.00	0.00	10.23
Services	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Chihuahua	55	29,819	625,139,081.0	1.07	2.66	13.36
Food	--	--	--	--	--	--
Textiles	8	1,362	16,025,187.0	3.86	7.82	11.09
Shoe and leather	--	--	--	--	--	--
Furniture	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	7	12,773	314,295,993.0	0.28	0.66	12.17
Tools and equipment	3	56	2,012,534.0	17.85	20.42	7.14
Electric/electronic goods	5	238	5,224,097.0	12.31	8.21	21.01
Electric/electronic componei	12	9,780	188,636,226.0	0.11	0.33	15.19
Toys	--	--	--	--	--	--
Other industries	13	3,072	53,149,657	0.86	2.59	17.42
Services	7	2,538	45,795,387.0	17.74	22.74	8.12
Ensenada	20	3,871	124,487,546	4.06	0.69	32.37
Food	--	--	--	--	--	--
Textiles	3	247	3,260,441	3.71	0.61	37.65
Shoe and leather	0	12	63,000	0.00	0.00	0.00
Furniture	3	461	80,237,819	0.00	0.00	90.89
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Tools and equipment	--	--	--	--	--	--
Electric/electronic goods	--	--	--	--	--	--
Electric/electronic componei	3	806	12,355,658	1.58	0.33	11.66
Toys	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Other industries	11	2,170	26,517,563	6.91	2.21	33.90
Services	--	--	--	--	--	--

Notes: (1) n.i. = figures are not included due to confidentiality restrictions (2 or less plants in the industry). The number of firms and workers, and value added are included under "other industries"; nevertheless, the percentage of domestic inputs and technical workers in "other industries" do not account for the unincluded industries.
(2) Two dashes (--) indicate that the industry did not exist in the municipality in 1990.
(3) The value of domestic inputs purchased by the industry as a percentage of total inputs is given under "% domestic inputs total (total)."
(4) The value of domestic inputs purchased by the industry as a percentage of value added is given under "% domestic inputs total (VA)."
(5) National domestic-input and technical-employment percentages are given for 1989; all other figures are for 1990.
(6) Value-figures are given in Mexican pesos.

Source: INEGI.

Table B.1 (continued): Maquiladora sector's regional characteristics (1990 figures)

Municipality Industry	Number of firms	Number of workers	Value added in Mexico	% domestic inputs (total)	% domestic inputs (VA)	% technical workers
Hermosillo	12	3,744	54,495,417	0.05	0.60	18.56
Food	--	--	--	--	--	--
Textiles	5	575	14,509,102	8.94	1.87	29.57
Shoe and leather	--	--	--	--	--	--
Furniture	--	--	--	--	--	--
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	--	--	--	--	--	--
Tools and equipment	--	--	--	--	--	--
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componei	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Toys	--	--	--	--	--	--
Other industries	7	2,999	38,928,305	0.00	0.00	11.02
Services	--	--	--	--	--	--
Juarez	238	124,061	2,691,380,134.0	0.99	2.75	13.16
Food	4	1,038	41,597,079.0	19.07	57.27	7.51
Textiles	28	9,135	159,404,063.0	0.02	0.10	14.30
Shoe and leather	8	906	20,712,833.0	5.43	13.28	6.29
Furniture	24	7,562	218,410,534.0	1.61	4.32	15.26
Chemical products	5	879	13,391,868.0	0.02	0.10	11.49
Transportation equipment	25	33,655	772,764,098.0	0.35	0.90	14.84
Tools and equipment	5	701	15,858,993.0	0.18	0.59	8.27
Electric/electronic goods	26	16,281	342,813,638.0	1.39	3.73	9.95
Electric/electronic componei	69	39,352	849,215,361.0	0.46	1.44	14.61
Toys	--	--	--	--	--	--
Other industries	34	6,714	139,348,751.0	0.75	1.49	13.49
Services	10	7,838	117,862,916.0	4.50	3.05	3.88
Matamoros	82	37,870	1,350,391,532.0	0.97	3.30	10.57
Food	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Textiles	3	2,306	35,516,268.0	0.00	0.02	6.76
Shoe and leather	--	--	--	--	--	--
Furniture	7	476	10,681,654.0	7.25	11.51	14.71
Chemical products	4	1,214	22,256,210.0	1.12	1.47	6.67
Transportation equipment	17	13,737	352,043,373.0	0.99	7.76	8.92
Tools and equipment	3	721	21,140,159.0	4.62	10.08	17.34
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componei	25	16,279	848,631,533.0	0.53	0.66	12.83
Toys	--	--	--	--	--	--
Other industries	19	2,905	54,770,143	6.14	12.73	9.59
Services	4	222	5,245,091.0	1.45	27.35	2.70
Monterrey (Metropolitan area)	31	6,013	163,554,304.0	9.65	19.19	9.66
Food	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Textiles	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Shoe and leather	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Furniture	4	226	8,067,275.0	0.00	43.62	9.29
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	3	2,535	52,564,161.0	0.16	0.49	6.63
Tools and equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componei	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Toys	5	1,015	26,881,742.0	74.85	20.13	0.30
Other industries	9	1,272	44,835,702	15.12	21.85	22.41
Services	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Mexicali	112	21,820	683,913,406	3.34	1.72	23.35
Food	5	1,124	13,160,855	0.00	16.07	2.05
Textiles	25	3,397	49,197,460	0.18	0.04	31.65
Shoe and leather	--	--	--	--	--	--
Furniture	11	2,895	289,202,048	11.61	0.45	46.63
Chemical products	--	--	--	--	--	--
Transportation equipment	11	2,409	60,663,738	4.56	5.90	20.92
Tools and equipment	5	955	15,384,807	0.00	0.00	8.38
Electric/electronic goods	8	1,750	25,499,226	0.51	1.10	9.20
Electric/electronic componei	20	4,755	158,850,870	3.86	2.30	17.10
Toys	5	833	12,127,012	1.46	1.72	36.61
Other industries	16	3,425	53,454,247	1.11	1.10	22.07
Services	6	276	6,366,143	0.33	0.11	10.51

Notes: (1) n.i. = figures are not included due to confidentiality restrictions (2 or less plants in the industry). The number of firms and workers, and value added are included under "other industries"; nevertheless, the percentage of domestic inputs and technical workers in "other industries" do not account for the unincluded industries.
(2) Two dashes (--) indicate that the industry did not exist in the municipality in 1990.
(3) The value of domestic inputs purchased by the industry as a percentage of total inputs is given under "% domestic inputs total (total)."
(4) The value of domestic inputs purchased by the industry as a percentage of value added is given under "% domestic inputs total (VA)."
(5) National domestic-input and technical-employment percentages are given for 1989; all other figures are for 1990.
(6) Value-figures are given in Mexican pesos.

Source: INEGI.

Table B.1 (continued): Maquiladora sector's regional characteristics (1990 figures)

Municipality Industry	Number of firms	Number of workers	Value added in Mexico	% domestic inputs (total)	% domestic inputs (VA)	% technical workers
Nogales	50	17,909	218,860,858	1.15	1.05	20.64
Food	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Textiles	4	1,241	19,631,900	0.00	0.00	11.44
Shoe and leather	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Furniture	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	5	1,147	19,885,194	0.00	0.00	18.57
Tools and equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componen	21	10,296	120,464,155	2.08	1.46	20.00
Toys	--	--	--	--	--	--
Other industries	20	5,225	58,879,609	0.76	1.18	23.09
Services	--	--	--	--	--	--
Nuevo Laredo	49	15,773	316,081,383.0	0.82	2.46	14.11
Food	--	--	--	--	--	--
Textiles	--	--	--	--	--	--
Shoe and leather	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Furniture	5	358	5,824,362.0	1.22	2.63	12.01
Chemical products	4	592	5,539,822.0	1.99	2.44	12.67
Transportation equipment	16	8,028	210,884,871.0	0.26	0.84	16.78
Tools and equipment	--	--	--	--	--	--
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componen	6	1,780	32,969,259.0	0.86	3.05	17.53
Toys	--	--	--	--	--	--
Other industries	18	5,010	60,841,043	4.59	11.90	11.59
Services	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Piedras Negras	32	7,156	97,812,287.0	1.36	2.60	12.59
Food	3	564	7,919,052.0	0.05	0.18	15.43
Textiles	5	2,358	27,469,306.0	0.00	0.00	13.74
Shoe and leather	--	--	--	--	--	--
Furniture	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Chemical products	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Transportation equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Tools and equipment	--	--	--	--	--	--
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componen	7	1,461	20,458,060.0	0.05	0.10	12.18
Toys	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Other industries	17	2,773	41,965,869	5.12	5.48	10.80
Services	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Reynosa	50	23,437	462,167,951.0	1.61	7.21	11.42
Food	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Textiles	3	825	10,860,993.0	0.02	0.04	8.73
Shoe and leather	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Furniture	6	290	4,652,459.0	2.27	10.58	5.86
Chemical products	3	150	1,576,398.0	0.03	0.13	16.67
Transportation equipment	4	5,142	117,349,568.0	0.07	0.34	9.98
Tools and equipment	3	615	17,207,135.0	5.76	14.38	28.29
Electric/electronic goods	4	1,930	40,001,791.0	0.69	3.43	9.48
Electric/electronic componen	13	11,656	199,628,226.0	0.26	1.42	10.93
Toys	--	--	--	--	--	--
Other industries	14	2,829	70,891,381	3.37	11.51	16.85
Services	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Saltillo	7	1,227	44,457,255.0	9.72	16.60	14.34
Food	--	--	--	--	--	--
Textiles	--	--	--	--	--	--
Shoe and leather	--	--	--	--	--	--
Furniture	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Chemical products	--	--	--	--	--	--
Transportation equipment	5	947	27,147,561.0	3.20	7.28	11.72
Tools and equipment	--	--	--	--	--	--
Electric/electronic goods	--	--	--	--	--	--
Electric/electronic componen	--	--	--	--	--	--
Toys	--	--	--	--	--	--
Other industries	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Services	--	--	--	--	--	--

Notes: (1) n.i. = figures are not included due to confidentiality restrictions (2 or less plants in the industry). The number of firms and workers, and value added are included under "other industries"; nevertheless, the percentage of domestic inputs and technical workers in "other industries" do not account for the unincluded industries.
(2) Two dashes (--) indicate that the industry did not exist in the municipality in 1990.
(3) The value of domestic inputs purchased by the industry as a percentage of total inputs is given under "% domestic inputs total (total)."
(4) The value of domestic inputs purchased by the industry as a percentage of value added is given under "% domestic inputs total (VA)."
(5) National domestic-input and technical-employment percentages are given for 1989; all other figures are for 1990.
(6) Value-figures are given in Mexican pesos.

Source: INEGI.

Table B.1 (continued): Maquiladora sector's regional characteristics (1990 figures)

Municipality Industry	Number of firms	Number of workers	Value added in Mexico	% domestic inputs (total)	% domestic inputs (VA)	% technical workers
Tecate	48	7,575	112,361,825	0.28	0.23	33.89
Food	--	--	--	--	--	--
Textiles	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Shoe and leather	--	--	--	--	--	--
Furniture	14	3,514	49,618,340	0.13	0.22	44.99
Chemical products	4	552	8,295,473	0.01	0.00	19.02
Transportation equipment	3	137	1,526,015	0.00	0.00	66.42
Tools and equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic goods	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Electric/electronic componei	16	1,323	22,387,937	0.44	0.08	12.02
Toys	--	--	--	--	--	--
Other industries	8	1,794	27,498,636	0.22	0.01	30.09
Services	3	255	3,035,424	0.00	0.00	5.88
Tijuana	319	59,614	955,428,645	0.77	0.79	20.28
Food	3	301	6,645,807	37.08	0.12	6.64
Textiles	35	3,330	38,248,711	3.37	0.85	33.78
Shoe and leather	6	1,018	11,712,068	1.31	0.07	42.44
Furniture	78	12,727	340,424,342	5.67	1.12	22.71
Chemical products	24	4,636	35,924,467	0.44	0.42	31.62
Transportation equipment	11	1,459	22,510,225	1.02	0.50	34.61
Tools and equipment	6	664	8,674,706	0.25	1.20	36.30
Electric/electronic goods	15	4,697	67,969,638	0.05	0.03	17.59
Electric/electronic componei	84	17,697	240,801,644	0.15	0.42	14.46
Toys	7	3,442	47,030,648	3.94	2.58	15.02
Other industries	32	7,755	108,600,377	0.79	0.30	14.66
Services	18	1,888	26,886,012	1.64	1.55	19.70
Torreon-Gomez-Lerdo	51	8,288	91,942,140.0	5.20	7.92	8.10
Food	--	--	--	--	--	--
Textiles	44	7,421	66,113,897.0	2.47	4.14	7.75
Shoe and leather	--	--	--	--	--	--
Furniture	--	--	--	--	--	--
Chemical products	--	--	--	--	--	--
Transportation equipment	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Tools and equipment	--	--	--	--	--	--
Electric/electronic goods	--	--	--	--	--	--
Electric/electronic componei	--	--	--	--	--	--
Toys	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
Other industries	7	830	23,896,719	0.00	37.28	7.03
Services	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.

Notes: (1) n.i. = figures are not included due to confidentiality restrictions (2 or less plants in the industry). The number of firms and workers, and value added are included under "other industries"; nevertheless, the percentage of domestic inputs and technical workers in "other industries" do not account for the unincluded industries.
(2) Two dashes (--) indicate that the industry did not exist in the municipality in 1990.
(3) The value of domestic inputs purchased by the industry as a percentage of total inputs is given under "% domestic inputs total (total)."
(4) The value of domestic inputs purchased by the industry as a percentage of value added is given under "% domestic inputs total (VA)."
(5) National domestic-input and technical-employment percentages are given for 1989; all other figures are for 1990.
(6) Value-figures are given in Mexican pesos.

Source: INEGI.

Table B.2: Location quotients

Industry Municipalities	Location quotients in terms of: Employment	Value added	Number of firms	Employment share
Textiles				
Torreon-Gomez Palacio-Lerdo	10.134	12.865	5.785	17.7%
Piedras Negras	3.729	5.024	1.048	5.6%
Mexicali	1.762	1.287	1.497	8.1%
Hermosillo	1.738	4.763	2.794	1.4%
Agua Prieta	0.984	1.245	0.610	1.2%
Juarez	0.833	1.060	0.789	21.7%
Nogales	0.784	1.605	0.536	3.0%
Ensenada	0.722	0.469	1.006	0.6%
Matamoros	0.689	0.471	0.245	5.5%
Tijuana	0.632	0.716	0.736	7.9%
Chihuahua	0.517	0.459	0.975	3.2%
Reynosa	0.398	0.420	0.402	2.0%
Tecate	0.356	1.054	0.140	0.6%
Monterrey (Metropolitan area)	0.207	0.181	0.216	0.3%
Acuna	0.170	0.188	0.172	0.5%
Nuevo Laredo	0.004	0.001	0.000	0.0%
Saltillo	0.000	0.000	0.000	0.0%
Furniture				
Tecate	7.186	7.918	2.133	11.4%
Tijuana	3.307	6.388	1.788	41.4%
Mexicali	2.055	7.582	0.718	9.4%
Ensenada	1.845	11.557	1.097	1.5%
Juarez	0.944	1.455	0.737	24.6%
Hermosillo	0.703	0.347	0.000	0.6%
Monterrey (Metropolitan area)	0.582	0.884	0.944	0.7%
Nuevo Laredo	0.352	0.330	0.746	1.2%
Acuna	0.295	0.498	0.938	0.9%
Matamoros	0.195	0.142	0.624	1.5%
Reynosa	0.192	0.180	0.878	0.9%
Saltillo	0.152	0.049	1.045	0.0%
Piedras Negras	0.102	0.155	0.229	0.2%
Agua Prieta	0.067	0.026	0.332	0.1%
Nogales	0.023	0.340	0.146	0.1%
Chihuahua	0.001	0.000	0.133	0.0%
Torreon-Gomez Palacio-Lerdo	0.000	0.000	0.000	0.0%
Transportation equipment				
Saltillo	3.712	2.422	8.761	1.0%
Nuevo Laredo	2.448	2.647	4.005	8.1%
Chihuahua	2.028	1.994	1.561	12.9%
Monterrey (Metropolitan area)	1.962	1.275	1.187	2.6%
Matamoros	1.745	1.034	2.543	13.9%
Acuna	1.402	1.213	0.944	4.2%
Juarez	1.305	1.139	1.288	34.0%
Agua Prieta	1.259	0.907	1.115	1.5%
Reynosa	1.055	1.007	0.981	5.2%
Mexicali	0.531	0.352	1.205	2.4%
Nogales	0.308	0.360	1.227	1.2%
Piedras Negras	0.238	0.377	0.767	0.4%
Torreon-Gomez Palacio-Lerdo	0.173	0.269	0.241	0.0%
Tijuana	0.118	0.093	0.423	1.5%
Ensenada	0.112	0.033	0.613	0.1%
Tecate	0.087	0.054	0.767	0.1%
Hermosillo	0.000	0.000	0.000	0.0%

Source: Calculated from INEGI data.

Table B.2 (continued): Location quotients

Industry / Municipalities	Location quotients in terms of: Employment	Value added	Number of firms	Employment share
Electric and electronic goods				
Saltillo	1.235	2.782	0.000	0.3%
Juarez	1.170	1.091	2.016	30.5%
Reynosa	0.734	0.741	1.477	3.6%
Mexicali	0.715	0.319	1.318	3.3%
Tijuana	0.703	0.609	0.868	8.8%
Agua Prieta	0.659	1.002	1.678	0.8%
Hermosillo	0.553	0.609	1.538	0.4%
Nogales	0.376	0.139	0.738	1.4%
Monterrey (Metropolitan area)	0.138	0.134	1.191	0.2%
Nuevo Laredo	0.110	0.117	0.377	0.4%
Chihuahua	0.071	0.072	1.678	0.4%
Piedras Negras	0.044	0.066	1.154	0.1%
Tecate	0.044	0.021	0.385	0.1%
Matamoros	0.034	0.014	0.225	0.3%
Acuna	0.016	0.017	0.473	0.0%
Ensenada	0.000	0.000	0.000	0.0%
Torreon-Gomez Palacio-Lerdo	0.000	0.000	0.000	0.0%
Electric and electronic components				
Nogales	2.153	2.124	2.055	8.1%
Reynosa	1.862	1.667	1.272	9.2%
Matamoros	1.610	2.425	1.492	12.8%
Chihuahua	1.234	1.505	1.780	1.4%
Juarez	1.228	1.164	1.068	7.7%
Agua Prieta	1.188	1.218	1.419	31.0%
Tijuana	1.112	0.973	1.289	13.9%
Acuna	0.986	1.121	1.004	3.0%
Mexicali	0.816	0.896	0.874	3.7%
Ensenada	0.780	0.383	0.734	0.6%
Piedras Negras	0.765	0.807	1.071	1.1%
Tecate	0.654	0.769	1.631	1.0%
Hermosillo	0.552	0.789	0.816	0.4%
Nuevo Laredo	0.423	0.403	0.599	1.4%
Monterrey (Metropolitan area)	0.148	0.070	0.158	0.2%
Saltillo	0.000	0.000	0.000	0.0%
Torreon-Gomez Palacio-Lerdo	0.000	0.000	0.000	0.0%

Source: Calculated from INEGI data.

Table B.3: Localization coefficients

Industry	Localization Coefficient (Employment)
Textiles	0.289
Furniture	0.452
Transportation equipment	0.303
Electric and electronic goods	0.229
Electric and electronic components	0.164

Source: Calculated from INEGI data.

Appendix C

Regression results

C.1 Regression equations

In Chapter 4, we used a constant elasticity of substitution (CES) production function for a firm to derive the labor-demand function for an industry at a particular location [See Section 4.1]. We introduced external economies of agglomeration as a function $\phi = \phi(N, V)$, were N represents population and is use a measure of urbanization and V represents industry size, either in terms of value added Q or employment L. Given that there is no theoretically defined functional form for $\phi(\cdot)$, we experimented with different functional forms to produce five regression models. We report results for all of them and use those that present significant regression coefficients. Below, we present the models along with the functional form being used and the elasticities of city and industry size, ε_N and ε_V, respectively. The elasticities of city and industry size show the percent change in a firm's output as a result of a 1% increase in city size N and industry size V, respectively. Mathematically,

$$\varepsilon_N = \frac{\partial \log q_i}{\partial \log N}$$

and

$$\varepsilon_V = \frac{\partial \log q_i}{\partial \log V}.$$

Finally, for each model, we present the criteria for testing the significance of localization and urbanization coefficients. In all cases, $\alpha = \left(\frac{-s}{1+s}\right) \log j' + \left(\frac{1}{1+s}\right) \log r$ and $\beta_1 = \left(\frac{-1}{1+s}\right)$; the rest of the coefficients vary from model to model.

Model A We use functional form $\phi(N, V) = N^b \exp^{\frac{-c}{L}}$ to produce a log-inverse combination of population and industry employment. The corresponding elasticities are $\varepsilon_N = b$, $\varepsilon_V = c/L$. $\beta_2 = constant$; $\beta_3 = \left(\frac{-bs}{1+s}\right)$; $\beta_4 = \left(\frac{cs}{1+s}\right)$.

$$\log L_t = \alpha + \beta_1 \log w_t + \beta_2 \log Q_t + \beta_3 \log N_t + \beta_4 \left(\frac{1}{L_t}\right) + u_t. \qquad (C.1)$$

Model B We let $\phi(N, V) = \exp^{\frac{-b}{N} + \frac{-c}{L}}$, yieldin an inverse-inverse combination of population and employment, with elasticities $\varepsilon_N = b/N$, $\varepsilon_V = c/L$. $\beta_2 = constant$; $\beta_3 = \left(\frac{bs}{1+s}\right)$; $\beta_4 = \left(\frac{cs}{1+s}\right)$.

$$\log L_t = \alpha + \beta_1 \log w_t + \beta_2 \log Q_t + \beta_3 \left(\frac{1}{N_t}\right) + \beta_4 \left(\frac{1}{L_t}\right) + u_t. \qquad (C.2)$$

Model C We use $\phi(N, V) = N^b \exp^{\frac{-c}{Q}}$ to prroduce a log-inverse combination of population and value-added; the elasticities are $\varepsilon_N = b$, $\varepsilon_V = c/L$. $\beta_2 = constant$; $\beta_3 = \left(\frac{-bs}{1+s}\right)$; $\beta_4 = \left(\frac{cs}{1+s}\right)$.

$$\log L_t = \alpha + \beta_1 \log w_t + \beta_2 \log Q_t + \beta_3 \log N_t + \beta_4 \left(\frac{1}{Q_t}\right) + u_t. \qquad (C.3)$$

Model D Functional form $\phi(N, V) = N^b Q^c$ is used to produce a log-log combination of population and value-added by the industry; the elasticities are $\varepsilon_N = b$, $\varepsilon_V = c$. $\beta_2 = \left(\frac{1+s-cs}{1+s}\right)$; $\beta_3 = \left(\frac{-bs}{1+s}\right)$.

$$\log L_t = \alpha + \beta_1 \log w_t + \beta_2 \log Q_t + \beta_3 \log N_t + u_t. \qquad (C.4)$$

Model E Finally, we let $\phi(N, V) = \exp^{\frac{-b}{N}} Q^c$, producing an inverse-log combination of population and value-added; the elasticities are $\varepsilon_N = b/N$,

$\varepsilon_V = c$. $\beta_2 = \left(\frac{1+s-cs}{1+s}\right)$; $\beta_3 = \left(\frac{bs}{1+s}\right)$.

$$\log L_t = \alpha + \beta_1 \log w_t + \beta_2 \log Q_t + \beta_3 \left(\frac{1}{N_t}\right) + u_t. \quad \text{(C.5)}$$

C.1.1 Hypothesis testing criteria

For all models, the theoretical sign of the wage coefficient $\hat{\beta}_1$ should be negative since the use of labor inputs will decrease as the price of labor—i.e., the wage level—increases. Thus, a negative $\hat{\beta}_1$ coefficient indicates the theoretical validity of the regression model; furthermore, we must keep this consideration in mind at all times and check for it.

Next, we tested the external factors coefficients must be tested to determine the existence of localization and urbanization economies and diseconomies. We describe the test criteria for each of them below.

Localization economies

In models A, B, and C, the localization coefficient c is given by

$$c = \frac{\hat{\beta}_4}{1 + \hat{\beta}_1}.$$

Thus, if $-1 < \hat{\beta}_1 < 0$, localization economies ($c > 0$) exist if and only if $\hat{\beta}_4 > 0$. Therefore, we test the null hypothesis $H_o : \hat{\beta}_4 = 0$ versus the alternative hypothesis $H_1 : \hat{\beta}_4 > 0$. If $\hat{\beta}_1 < -1$, the alternative hypothesis becomes $H_1 : \hat{\beta}_4 < 0$.

In models D and E,

$$c = \frac{1 - \hat{\beta}_2}{1 + \hat{\beta}_1},$$

so that, for $-1 < \hat{\beta}_1 < 0$, $c > 0$ if and only if $\hat{\beta}_2 < 1$. Hence, we test the null hypothesis $H_o : \hat{\beta}_2 = 1$ against the alternative hypothesis $H_1 : \hat{\beta}_2 < 1$. If $\hat{\beta}_1 < -1$, $c > 0$ if and only if $\hat{\beta}_2 > 1$, and the alternative hypothesis becomes $H_1 : \hat{\beta}_2 > 1$. In all models, if $\hat{\beta}_1 = 0$ or $\hat{\beta}_1 = -1$, the equation is under-identified; finally, as stated earlier, if $\hat{\beta}_1 > 0$, the coefficient is theoretically unacceptable.

Urbanization economies

In models A, C, and D, urbanization economies exist whenever

$$b = \frac{-\hat{\beta}_3}{1+\hat{\beta}_1} > 0.$$

Thus, if $-1 < \hat{\beta}_1 < 0$, $b > 0$ if and only if $\hat{\beta}_3 < 0$; the corresponding hypotheses are $H_o : \hat{\beta}_3 = 0$ and $H_1 : \hat{\beta}_3 < 0$. If $\hat{\beta}_1 < -1$, the alternative hypothesis becomes $H_1 : \hat{\beta}_3 > 0$.

In models B and E,

$$b = \frac{\hat{\beta}_3}{1+\hat{\beta}_1} > 0,$$

so that, for $-1 < \hat{\beta}_1 < 0$, $b > 0$ if and only if $\hat{\beta}_3 > 0$ and the corresponding test is $H_o : \hat{\beta}_3 = 0$ versus $H_1 : \hat{\beta}_3 > 0$. If $\hat{\beta}_1 < -1$, the alternative hypothesis becomes $H_1 : \hat{\beta}_3 < 0$.

Again, in all models, if $\hat{\beta}_1 = 0$ or $\hat{\beta}_1 = -1$, the model is under-identified, and if $\hat{\beta}_1 > 0$, the coefficient is theoretically unacceptable.

C.2 Results

Table C.1 summarizes the regression results for the five econometric models. The results are discussed in Section 4.2.

Table C.1: Regression results

Textiles--regression coefficients

Variable	Model A	Model B	Model C	Model D	Model E
Constant term	-0.431	-0.279	-1.061	-2.427	-3.645
	(-0.343)	(-.166)	(-.496)	(-1.988)	(-2.807)
Wage (log)	-0.638	-0.634	-0.734	-0.696	-0.708
	(-8.126)	(-7.947)	(-6.932)	(-7.129)	(-6.264)
Value added (log)	0.821	0.811	0.958	1.028	1.037
	(9.075)	(8.268)	(9.272)	(0.626)*	(0.700)*
Value added (inv)	--	--	6.59e5	--	--
	--	--	(0.924)	--	--
Population (log)	1.391	--	-0.068	-0.086	--
	(2.94e-2)	--	(-1.449)	(-2.149)	--
Population (inv)	--	-289.5	--	--	-1.53e4
	--	(-4.39e-02)	--	--	(-2.011)
Workers (inv)	113.7	118.2	--	--	--
	(2.668)	(2.777)	--	--	--
R-squared	0.99	0.99	0.99	0.98	0.98

Furniture--regression coefficients

Coefficient	Model A	Model B	Model C	Model D	Model E
Constant term	0.357	-2.870	0.264	0.156	-2.119
	(.272)	(-2.422)	(0.206)	(0.114)	(-2.382)
Wage (log)	-0.872	-0.845	-0.862	-0.813	-0.786
	(-7.309)	(-7.142)	(-7.667)	(-6.997)	(-6.951)
Value added (log)	1.042	1.042	1.039	0.966	0.963
	(11.985)	(12.135)	(12.971)	(-0.616)*	(-0.694)*
Value added (inv)	--	--	-1.15e4	--	--
	--	--	(-1.074)	--	--
Population (log)	-0.222	--	-0.219	-0.151	--
	(-1.983)	--	(-2.073)	(-1.631)	--
Population (inv)	--	-3.12e4	--	--	2.48e4
	--	(-1.975)	--	--	(1.759)
Workers (inv)	-1.423	-1.489	--	--	--
	(-.977)	(-1.022)	--	--	--
R-squared	0.98	0.98	0.98	0.98	0.98

Transportation equipment--regression coefficients

Coefficient	Model A	Model B	Model C	Model D	Model E
Constant term	-1.174	-5.839	-3.671	-4.296	-5.42
	(-0.225)	(-1.276)	(-.899)	(-1.424)	(-2.108)
Wage (log)	-0.438	-0.243	-0.324	-0.259	-0.263
	(-1.083)	(-0.790)	(-.953)	(-0.822)	(-0.948)
Value added (log)	0.777	0.894	0.867	0.860	0.881
	(4.764)	(6.420)	(7.420)	(-2.61)*	(-2.394)*
Value added (inv)	--	--	9.1e4	--	--
	--	--	(0.137)	--	--
Population (log)	-0.045	--	-0.065	-0.051	--
	(-0.484)	--	(-0.858)	(-0.777)	--
Population (inv)	--	-1.60e4	--	--	1.53e4
	--	(-1.356)	--	--	(1.494)
Workers (inv)	63.456	2.678	--	--	--
	(0.746)	(0.037)	--	--	--
R-squared	0.97	0.98	0.98	0.97	0.98

Notes: -Figures in parethesis represent t-statistics.
-In models D and E, t-statistic's for log(value added) consider a null hypothesis where the coefficient is equal to one.

Table C.1 (continued): Regression results

Electric/electronic goods--regression coefficients

Coefficient	Model A	Model B	Model C	Model D	Model E
Constant term	0.715	1.823	-2.142	-2.068	-2.057
	(0.249)	(0.559)	(-0.638)	(-0.911)	(-0.795)
Wage (log)	-0.876	-0.883	-0.817	-0.979	-0.788
	(-3.052)	(-3.350)	(-2.601)	(-2.792)	(-3.021)
Value added (log)	0.846	0.810	0.972	0.975	0.986
	(8.120)	(7.177)	(8.488)	(-0.287)*	(-0.157)*
Value added (inv)	--	--	-5173	--	--
	--	--	(-2.6-02)	--	--
Population (log)	0.036	--	0.046	4.125	--
	(0.284)	--	(0.334)	(0.309)	--
Population (inv)	--	-6750	--	--	-1.45e3
	--	(-.404)	--	--	(-0.078)
Workers (inv)	24.286	32.935	--	--	--
	(1.581)	(1.930)	--	--	--
R-squared	0.97	0.96	0.96	0.96	0.96

Electric/electronic components--regression coefficients

Coefficient	Model A	Model B	Model C	Model D	Model E
Constant term	3.531	5.544	1.854	-2.578	-2.922
	(0.756)	(0.896)	(0.449)	(-0.926)	(-1.066)
Wage (log)	-0.624	-0.527	-0.708	-0.479	-0.477
	(-1.719)	(-1.330)	(-2.062)	(-1.611)	(-1.608)
Value added (log)	0.368	0.460	0.594	0.865	0.868
	(1.334)	(1.739)	(3.111)	(-2.126)*	(-2.058)*
Value added (inv)	--	--	6.03e6	--	--
	--	--	(1.580)	--	--
Population (log)	0.366	--	0.214	-1.88e-2	--
	(1.647)	--	(1.256)	(-0.253)	--
Population (inv)	--	2.94e4	--	--	4.58e3
	--	(1.148)	--	--	(0.377)
Workers (inv)	815.1	586.7	--	--	--
	(1.923)	(1.651)	--	--	--
R-squared	0.94	0.93	0.95	0.96	0.96

Notes: -Figures in parethesis represent t-statistics.
-In models D and E, t-statistic's for log(value added) consider a null hypothesis where the coefficient is equal to one.

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