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Agglomeration Economies and Urban Manufacturing Growth in the Northern Border Cities of Mexico

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Abstract: The objective of this paper is to investigate the effect of agglomeration economies on the manufacturing sector of the northern border cities of Mexico. It is assumed that economic globalization is determining a trend towards the re-localization of manufacturing activities towards the northern border region. As a result, an increase in manufacturing and urban agglomeration is occuring in that region. The present research is based on the hypothesis that agglomeration has had a positive impact on urban manufacturing growth in the northern cities studied. An econometric model was established to relate agglomeration with manufacturing growth. The results of the study revealed that the externalities caused by industrial specialization among industries make up one of the explicative factors of manufacturing employment growth during 1988-1993. The study included control variables of total initial urban employment and total initial wage level for the 1988-1993 period. Finally, when including the effect of urban agglomeration, using the population as a proxy, a positive but small impact on manufacturing employment growth was found.

Keywords: industrial studies, industralization, regional economy, analysis of growth and development.

Resumen: El estudio se enfoca en investigar el impacto de las economías de aglomeración sobre el crecimiento del sector manufacturero de las ciudades del norte de México. El análisis parte del supuesto de que la globalización económica tiene un papel determinante en la relocalización de las actividades manufactureras hacia la región del norte de México. Como resultado de esta tendencia, las principales ciudades de esta región han experimentado un incremento de la aglomeración industrial y

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urbana. La presente investigación se basa en la hipótesis de que dicha aglomeración tiene un impacto positivo sobre el crecimiento manufacturero urbano en las ciudades estudiadas. A fin de relacionar la aglomeración con el crecimiento manufacturero, se establece un modelo econométrico aplicado a una base de datos de corte transversal. Los resultados del estudio revelan que las externalidades causadas por la creciente aglomeración entre industrias relacionadas son un factor determinante para explicar el crecimiento del empleo manufacturero durante el periodo 1988-1993. Para el periodo de 1993 a 1998 se incluye el efecto de la aglomeración urbana del crecimiento manufacturero, utilizando el nivel de población urbana como proxi. El impacto de esta variable fue reducido pero positivo, lo que sugiere un efecto limitado de la aglomeración urbana en el crecimiento manufacturero.

Palabras clave: estudios industriales, industrialización, economía regional, análisis del crecimiento y desarrollo.

I. Urban Agglomeration and External Economies

As a result of the liberalization process established since the 1980s, the Mexican economy has experienced an important adjustment in its manufacturing sector. One of the most relevant changes has been the geographic restructuring of the industries of that sector. During the 1980s new determinants of manufacturing growth emerged, such as foreign investment and the opening of export markets abroad (Hanson, 1998). As a consequence of export oriented industrial growth, the northern border cities of Mexico have experienced an expansion in their manufacturing activities and population. During the 1990s, the agglomeration of economic activities has become one of the determinants for the manufacturing growth in that region, due to the advantages provided by geographic proximity.

Therefore, Mexican industrialization and urbanization have been experiencing a different pattern of geographic localization, based on the development of new urban industrial areas, with different characteristics than the large, traditional industrial cities such as Mexico City, Monterrey and Guadalajara. These emerging cities are characterized by the existence of concentration and specialization of specific manufacturing industries. Such is the case of Tijuana, which is focused on television assembly, Ciudad Juárez, which is primarily dedicated to the production of electrical components, and Saltillo, which is specialized in automobile assembly plants. Within this context, it is relevant to investigate whether the development of agglomeration economies and the emergence of new manufacturing centers can explain the rapid manufacturing growth observed in the most important northern border cities.

Taking into account this objective, it is important to analyze the development of those urban manufacturing centers with high economic activity and population growth in the northern border of Mexico. For this purpose, the theoretical concept of agglomeration economies is useful for the study of urban manufacturing growth from the perspective of the existence of regional externalities that affect the manufacturing firms established in those cities.

Recently, several authors have pointed out that agglomeration economies are a determining factor for the emergence and development of modern cities (Nakamura, 1985; Krugman and Livas, 1992; and Henderson, Kuncoro and Turner, 1995). It has also been pointed out that the existence of centripetal and centrifugal forces affects the pattern of economic growth of cities (Henderson, 1974; and Krugman, 1992a). The centripetal forces encourage the agglomeration process in two ways:

i) The workers need to be close to the final goods produced by firms located in an urban center (forward linkage).

ii) The firms should be located close to larger markets, in order to take advantage of the existence of increasing returns and to reduce transportation costs (backward linkage).

Regarding the centrifugal forces, the localization model generally considers the transportation costs or the land rent as the factors pushing toward regional decentralization.

Therefore, the general concept of agglomeration states that externalities are created by increasing returns at a firm level, the availability of factors of production and the reduction of transportation costs (Krugman, 1995b). According to Richardson (1973), agglomeration economies can be divided into location economies and urban economies. The first type is related to external economies resulting from regional specialization, and the second type shows the firms external economies, derived from the economic activity within an urban area.

With reference to local externalities, Marshall (1890) underlined the availability of pooled labor markets, production factors and technological spillovers as the factors determining the existence of regional

externalities. With respect to externalities derived from localization, several authors (Marshall, 1890; Arrow, 1962; and Romer, 1986) have pointed out that industrial specialization allows technological spillovers and generates external economies. On the other hand, Jacobs (1969) underlined that technological diffusion can be developed from the industrial diversity developed in a competitive market structure context from the regional industrial diversity. With respect to the growth of cities, Glaeser (1992) found that local competition and knowledge spillovers occur between industries within an urban area. Additionally, Hanson (1996) and Mendoza and Martínez (1999a) explained that for the case of a less developed country such as Mexico industrial agglomeration externalities, under the context of economic globalization, are generated by the proximity to labor and input markets related to specialization among industries.

For the case of urban externalities, Henderson (1974) stressed that the development of new urban centers is related to the mobility of the factors of production. For workers, transportation costs and urban wages are determinant for employment decisions. On one hand, city growth implies increasing transportation costs that arise from transport congestion and longer distance between the workers' housing and the industrial production establishments. On the other hand, higher wages attract workers to the cities. However, for investors the profits are the main determinant of investment decisions, taking into consideration competitive advantages and the proximity to the factors of production and final goods markets. The urban center equilibrium expansion path is obtained when the costs of city growth are offset by the external economies created by the specialization of production.

The present research seeks to estimate the impact of external economies, originated by industrial and urban agglomeration, on the manufacturing employment growth of the northern border cities of Mexico. The hypotheses of the study are the following:

1) Economic globalization and the establishment of the North American Free Trade Agreement (NAFTA) have encouraged the shift of the manufacturing production process from industrialized countries (USA) to less developed economies (Mexico). This phenomenon has intensified the industrial agglomeration and specialization in several northern border cities of Mexico (depending on the geographic proximity to the manufactures market).

2) Manufacturing and urban agglomeration generates externalities for the industries located in urban areas, due to the existence of specialized inputs.
3) The expansion of cities allows the presence of urban economies related to transportation costs and the proximity to the markets of the factors of production and final goods.

In this context, the general goal of the study is to evaluate the impact of the external economies on the manufacturing employment performance of the urban areas of the Mexican northern border region. The particular objectives of this paper are:

i) Estimate the impact of industrial agglomeration on employment growth in the manufacturing sector of the northern border cities of Mexico before and after NAFTA was established.
ii) Explain the patterns of industrial expansion of the most important cities of the northern border.
iii) Determine whether the level of urbanization (measured by population size) in the larger urban areas generates the existence of urbanization economies and rapid growth of the manufacturing sector.

II. Urban Manufacturing Development in Mexico

II.1. Urban Industrial Employment Trends and Structure

The composition of the urban manufacturing employment in Mexico has been characterized for being concentrated in three important urban centers: Mexico City, Monterrey and Guadalajara. The industrial model based on import substitution determined the regional characteristics of the growth of the manufacturing sector until the beginning of the 1980s.

The employment structure in the manufacturing sector, analyzed by urban areas, shows that in 1988, the majority of industries with a larger share of employment at a national level were located in Mexico City. In the year mentioned, this city concentrated the 8 most important manufacturing activities, in terms of their share in the national manufacturing employment. It is worth mentioning that the majority of these industries were oriented towards the domestic market. The

most representative are the chemical industry with 87.7% of national production, the plastic products industry with 69.9% and the printing and publishing industry with 58.1% (see Table 1).

However, by 1998 the cities of Monterrey and Guadalajara had developed some dynamic exporting industries (automobiles, autoparts and electronics). Likewise, the urban areas of Ciudad Juárez and Tijuana emerged as cities with important manufacturing employment, as a result of the *maquiladora* activities developed in those regions.

Table 1. Urban Industries with the Highest Employment, 1988

Area	Industry	Description	Employ-ment	Share in the Industry
Cd. Juárez	3831	Electric machinery equipment and accessories	54 760	36.60%
Mexico City	3420	Printing and publishing	48 399	58.08%
Mexico City	3212	Woven soft fibers	44 685	44.55%
Mexico City	3560	Plastic products	44 076	69.89%
Mexico City	3220	Clothing	43 657	35.87%
Mexico City	3814	Other metallic products	40 268	60.29%
Mexico City	3522	Other chemical substances	39 956	87.70%
Mexico City	3841	Car Industry	34 916	34.34%
Mexico City	3831	Machinery equipment and electric inputs	34 631	23.14%
León	3240	Footwear industry	33 832	52.20%

Source: Own elaboration with data from: *XIII Censo Industrial*, 1989, INEGI.

According to Table 1, in 1988 the industry exhibiting the highest level of employment for an urban area was electric machinery, equipment and accesories located in Ciudad Juárez, with 54 760 workers, and representing 36.6% of that industry at a national level. It is important to point out that the employment of that industry is derived from the export oriented maquiladora activities developed in that region since the 1960s. By 1998, the expansion of the maquiladora activities resulted in the inclusion of the electronic equipment, radio and television assembly industry located in the northern border cities of Tijuana and Ciudad Juárez, within the group of the 10 urban industries with the highest employment (see Table 2). On the other hand, the number of industries from Mexico City in that group was reduced from 8 in 1988 to 6 in 1998.

With respect to the 10 most rapidly growing urban industries, during the 1988-1998 period, the three industries with the fastest average annual rate of growth were located in the cities of Monterrey, Matamoros and Hermosillo. In addition, 7 of the 10 most rapidly growing

Table 2. Urban Industries with Highest Employment, 1998

Area	Industry	Description	Employ-ment	Share in the Industry
Cd. Juárez	3831	Electric machinery equipment and accessories	80 130	27.21%
León	3240	Footwear industry	67 810	59.44%
Mexico City	3420	Printing and publishing	64 359	44.74%
Mexico City	3220	Clothing	64 250	14.17%
Mexico City	3560	Plastic products	50 256	30.11%
Mexico City	3814	Other metallic products	48 472	35.54%
Cd. Juárez	3832	Electronic equipment radio and television	47 908	21.21%
Tijuana	3832	Electronic equipment radio and television	44 038	19.49%
Mexico City	3212	Woven soft fibers	42 023	29.40%
Mexico City	3522	Woven soft fibers	41 746	51.94%

Source: Own elaboration with data from: *XIII Censo Industrial*, 1999, INEGI.

urban industries were also established in relative small northern cities. Such is the case of Nuevo Laredo, Matamoros, Saltillo and Monclova (see Table 3). Once more, the most dynamic industries were related to export oriented maquiladora activities such as electronic equipment, radio and television assembly and electric machinery, equipment and accessories.

II.2. Changes in the Dynamics of the Manufacturing Industries of the Northern Border Cities

During the 1990s, the northern border cities of Mexico grew very rapidly. In particular, the larger cities along the border –such as Tijuana, Ciudad Juárez and Nuevo Laredo– exhibited an accelerated expansion in their manufacturing employment. Between 1988-1993, the cities of Tijuana, Hermosillo and Nuevo Laredo showed the most rapid manufacturing employment growth. The annual average rates

Table 3. The 10 fastest growing urban industries 1988-1998

Area	Indus-try	Description	Employ-ment 1988	Employ-ment 1998	AARG
Monterrey	3513	Synthetic and artificial fibers industry	4	3 016	66.25%
Matamoros	3213	Textiles	4	1 822	61.21%
Hermosillo	3832	Electronic equipment radio and television	11	4 517	60.18%
Tlaxcala	3130	Beverages industry	4	1 218	57.19%
Zacatecas	3240	Footwear industry	3	703	54.57%
Hermosillo	3831	Electric machinery equipment and accessories	12	2233	52.26%
Nuevo Laredo	3213	Textiles	2	361	51.96%
Saltillo	3611	Ceramics	7	1 044	50.05%
Monclova	3220	Clothing	30	4 124	49.23%
Saltillo	3410	Cellulose and paper industry	7	959	49.20%

Source: Own elaboration with data from: 1989 and 1999 *Censos Industriales*, INEGI.

of growth for those cities were 15.6, 11.9 and 7.7%, respectively (see Table 4). For the period from 1993 to 1998, manufacturing employment in the cities of Ciudad Juárez, Tijuana and Hermosillo increased rapidly. It is important to stress that the maquiladora share of the labor employment in the manufacturing sector of the states of Baja California, Chihuahua, and Tamaulipas in 1993 was 75.3, 76.6 and 70.3%, respectively (Calderón and Mendoza, 2000). These results show the predominance of that type of manufactures in the urban centers of the northern border.

The industries leading the manufacturing expansion in the urban areas included in this study were largely related to the maquiladora tariff regime, or export oriented assembly plants. In the case of the manufacturing industries under the maquiladora system, the industries of electronics and television assembly and electric materials stood out as the main industrial activities for the cities of Tijuana, Chihuahua and Matamoros. In the case of the assembly manufactures produced by multinationals, the automobile industry was preponderant in the city of Saltillo. Finally, the industries of machinery and equipment and construction materials, oriented mainly towards the domestic market, were predominantly located in Monterrey and Saltillo (see Table 5).

Table 4. Northern Border Cities: Average Annual Rates of Growth

Cities	1988-1993		
	Manufacturing Employment 1988	Manufacturing Employment 1993	Annual Average Rate of Growth
Tijuana	41 872	91 419	15.62%
Hermosillo	11 294	20 441	11.87%
Nuevo Laredo	12 368	18 190	7.72%
Ciudad Juárez	108 172	143 723	5.68%
Saltillo	33 330	42 982	5.09%
Torreón	41 791	52 361	4.51%
Chihuahua	42 340	50 776	3.63%
Monterrey	184 031	218 741	3.46%
Matamoros	35 951	41 620	2.93%

Cities	1993-1998		
	Manufacturing Employment 1993	Manufacturing Employment 1998	Annual Average Rate of Growth
Ciudad Juárez	**143 723**	**235 768**	9.90%
Tijuana	91 419	146 634	9.45%
Hermosillo	20 441	32 717	9.41%
Torreón	**52 361**	**80 974**	8.72%
Matamoros	41 620	56 841	6.23%
Chihuahua	**50 776**	**68 132**	5.88%
Nuevo Laredo	18 190	23 924	5.48%
Monterrey	**218 741**	**284 112**	5.23%
Saltillo	**42 982**	**54 244**	4.65%

Source: Own elaboration with data from: 1989 and 1999 *Censos Industriales*, INEGI.

Given the outstanding dynamism of the manufacturing activities in the larger cities in the northern border region (Tijuana, Ciudad Juárez and Monterrey), it is convenient to briefly analyze their structure and trends. The urban area of Ciudad Juárez participated with 4.74% of the national manufacturing employment in 1988 and increased to 5.6% in 1998. The 3 most important industries during the period were electric machinery, equipment and accessories, electronic equipment, radio and television assembly and textiles. These accounted for more than 70% of the employment of that urban area. It is also worth mentioning that the industry of electronic equipment, radio and tele-

Table 5. Northern Border: Urban Industries with the Largest Share of the National Industry

City	Industry	Description	City Employment	National Employment	Percentage Share
Monterrey	3822	Machinery and equipment	17 893	83 895	21.33%
Tijuana	3832	Electronic equipment radio and television	44 038	225 905	19.49%
Monterrey	3814	Other metallic products	18 303	136 391	13.42%
Matamoros	3832	Electronic equipment radio and television	20 752	225 905	9.19%
Monterrey	3831	Electric machinery equipment and accessories	25 398	294 452	8.63%
Saltillo	3612	Construction materials	4 449	53 516	8.31%
Torreón	3220	Apparel	36 543	453 414	8.06%
Tijuana	3560	Plastic products	13 156	166 884	7.88%
Chihuahua	3831	Electric machinery equipment and accessories	20 325	294 452	6.90%
Saltillo	3841	Automobile Industry	8 507	190 783	4.46%

Source: Own elaboration with data from: 1989 and 1999 *Censos Industriales*, INEGI.

vision assembly increased its share, both in the city manufacturing employment and in the specific industry employment at a national level. In 1988, the shares of that industry accounted for 10.0 and 13.8%, respectively, whereas, in 1998 the shares of that industry accounted for 20.3 and 21.2%, respectively (see Table 6). It is worth mentioning that in 1993, within the industry category of electric machinery and equipment, the most important activity in terms of employment (at the 6-digit level), was the manufacturing of parts for automobile electrical systems (see Table 7).

As it has been pointed out, the majority of the firms localized in Ciudad Juárez have the legal status of maquiladora, which allows them to import duty free all the inputs they require in the manufacturing process and export practically all output back to the country of origin. In that sense, the dynamics of that urban center is largely determined by the strategies of the multinational firms located in that city.

The second large urban manufacturing center is located in Tijuana, Baja California. In 1988 the number of employees in the manufacturing sector of Tijuana was 41 872, which represented 1.8% of the total national manufacturing sector employment. However, in 1998 that number increased to 146 634 and its share of national manufacturing

Table 6. Ciudad Juárez: Manufacturing Employment Share, 1988-1998

Industry	Description	Employment	Industry Share in the Urban Area	Industry Employment at a National Level	Share the National Industry
Total	**1988**	**108 172**	**100.00%**	**2 284 133**	**4.74%**
3831	Electric machinery equipment and accessories	54 760	50.62%	149 627	36.60%
3832	Electronic equipment radio and television	10 852	10.03%	78 667	13.79%
3213	Textiles	5 317	4.92%	21 709	24.49%
3900	Other manufacturing industries	3 743	3.46%	35 200	10.63%
3833	Domestic appliances	3 436	3.18%	21 947	15.66%
3822	Machinery and equipment	3 338	3.09%	63 090	5.29%
3823	Computer Industry	3 244	3.00%	16 999	19.08%
Total	**1998**	**235 768**	**100.00%**	**4 213 566**	**5.60%**
3831	Electric machinery equipment and accessories	180 130	33.99%	294 452	27.21%
3832	Electronic equipment radio and television	47 908	20.32%	225 905	21.21%
3213	Textiles	23 589	10.01%	86 954	27.13%
3841	Automobile Industry	15 322	6.50%	190 783	8.03%
3823	Computer Industry	8 920	3.78%	48 719	18.31%
3833	Domestic appliances	7 488	3.18%	47 518	15.76%
3220	Apparel	5 597	2.37%	453 414	1.23%

Source: Own elaboration with data from: 1989 and 1999 *Censos Industriales*, INEGI.

employment reached 3.5%. With respect to the structure of the manufacturing sector in that urban area, the industry of electronic equipment, radio and television assembly was predominant during the period. In 1988 that industry represented 18% of the total employment of the city, but by 1998 the share increased to 30%, with 44 038 employees. Other important industries in that city area were electric machinery, equipment and accessories and plastic products (see Table 8).

Once again the manufacturing employment dynamics were related to firms operating under the maquiladora regime. In particular, the dynamics of the urban manufacturing area of Tijuana is related to

Table 7. Ciudad Juárez: Electric Equipment and Electronic
Equipment Industries Disaggregated at 6-digit Level[1]

	Code	Occupied Personnel	%
Electric equipment and electric parts	3831	52 632	100.00%
Electric engines and equipment	383101	7 016	13.33%
Welding equipment	383102	7	0.01%
Parts for automobile electric system	383103	32 727	62.18%
Electric equipment for airplanes	383106	100	0.19%
Electric bateries	383107	1 270	2.41%
Electric materials	383109	9 007	17.11%
Light bulbs	383110	668	1.27%
Neon lights and luminous advertisment	383111	1 837	3.49%
Electronic equipment for radio and television	3832	24 837	100.00%
Communications equipment	383201	2 894	11.65%
Parts for communication equipment	383202	4 593	18.49%
Electronic equipment for radio and television	383203	56	0.23%
Radio and televisions	383204	2 625	10.57%
Components for radio and television	383206	14 669	59.06%

Source: Own elaboration with data from 1993 *Censos Industriales*, INEGI.
[1] According to the Mexican Classification of Activities and Products.

the Asian maquiladoras oriented towards television assembly. In particular, the maquiladora activities that stand out in that city are those related to the production of radios and televisions, as well as parts for communication equipment (see Table 9).

When analyzing the northern border cities, it is important to include the city of Monterrey, located in the northern border state of Nuevo León. Although it is not a border city, an important part of its manufacturing activities is oriented toward the export market. However, between 1988 and 1998, the share of its manufacturing employment in the national manufacturing sector decreased from 8.06 to 6.74%. Nevertheless, the share of the most important urban industries of Monterrey (metallic products, electric machinery, equipment and accessories, automobiles and the glass industry) remained constant over the period (see Table 10).

As shown in Table 11, when disaggregating the industry of electric machinery and equipment to the 6-digit level, the two most important manufacturing activities within that category, in terms of employment,

Table 8. Tijuana: Manufacturing Employment Share, 1988-1998

Industry	Description	Employment	Industry Share in the Urban Area	Industry Employment at a National Level	Share the National Industry
3832	Electronic equipment radio and television	7 523	17.97%	78 667	9.56%
3831	Electric machinery equipment and accessories	5 517	13.18%	149 627	3.69%
3320	Non-metallic furniture manufacturing	4 144	9.90%	58 597	7.07%
3833	Domestic appliances	2 216	5.29%	21 947	10.10%
3822	Machinery and equipment	2 168	5.18%	63 090	3.44%
3115	Bakery products	1 760	4.20%	89 573	1.96%
3220	Apparel	1 701	4.06%	121 715	1.40%
Total		**41 872**	**100.00%**	**2 284 133**	**1.83%**
3832	Electronic equipment radio and television	44 038	30.03%	225 905	19.49%
3560	Plastic products	13 156	8.97%	166 884	7.88%
3831	Electric machinery equipment and accessories	10 955	7.47%	294 452	3.72%
3320	Non-metallic furniture manufacturing	10 828	7.38%	134 401	8.06%
3900	Other manufacturing industries	7 029	4.79%	66 969	10.50%
3823	Computer Industry	6 987	4.76%	48 719	14.34%
3850	Precision instrument equipment manufacturing	6 449	4.40%	33 178	19.44%
Total		**146 634**	**100.00%**	**4 213 566**	**3.48%**

Source: Own elaboration with data from: 1989 and 1999 *Censos Industriales* INEGI.

were parts for automobile electrical systems (38.6%) and electric engines and equipment (19.4%). For the case of machinery and equipment, the most important actvities at the 6-digit level were metallic parts for machinery and equipment (49.7%) and air conditioning and refrigeration equipment (33.8%), respectively. It is worth mentioning that those industries are characterized by being mainly oriented towards the domestic market.

It is worthwhile to mention that the manufacturing industry of the city of Monterrey has been encouraged, in a large extent, by the

Table 9. Tijuana: Electric Equipment and Electronic Equipment Industries Disaggregated at 6-digit Level[1]

	Code	Occupied Personnel	%
Electric equipment and electric parts	3831	9 884	100.00%
Electric engines and equipment	383101	1 447	14.64%
Welding equipment	383102	33	0.33%
Parts for automobile electric system	383103	3	0.03%
Electric equipment for airplanes	383106	245	2.48%
Electric bateries	383107	1 500	15.18%
Electric materials	383109	4 113	41.61%
Light bulbs	383111	2 543	25.73%
Electronic equipment for radio and television	3 832	20632	100.00%
Communication equipment	383201	844	4.09%
Parts for communication equipment	383202	5 421	26.27%
Electronic equipment for radio and television	383203	8 44	4.09%
Radio and televisions	383204	6 738	32.66%
Records and magnetic tapes	383205	874	4.24%
Components for radio and television	383206	5 911	28.65%

Source: Own elaboration with data from 1993 *Censo Industrial*, INEGI.
[1] According to the Mexican Classification of Activities and Products.

strategies of local firms facing the process of globalization. This is the case of the Vitro and Alfa companies. Additionally, production chain-links have been developed in the autoparts industry, with the aim of providing parts for the automobile industry; this is the case of firms such as Metalsa, Nemak and Axa-Yazaki (Pozas, 1999).

In general, the urban manufacturing dynamics were closely related to the expansion of export oriented firms, in particular under the maquiladora regime (Calderón and Mendoza, 2000), and to the development of local industries which have been able to integrate themselves as suppliers to multinational firms or for the domestic market.

III. A Model of Urban Agglomeration Effects

The theoretical approach to study the impact of industrial and urban agglomeration on manufacturing employment growth is represented by a short run production function with only one labor input:

Table 10. Monterrey: Manufacturing Employment Share, 1988-1998

Indus-try	Description	Employ-ment	Industry Share in the Urban Area	Industry Employ-ment at a National Level	Share the National Industry
Total	**1988**	184 031	100.00%	2 284 133	8.06%
3831	Electric machinery equipment and accessories	16 241	8.83%	149 627	10.85%
3822	Machinery and equipment	12 970	7.05%	63 090	20.56%
3620	Glass	12 374	6.72%	26 243	47.15%
3814	Other metallic products	11 150	6.06%	66 790	16.69%
3710	Iron and steel Industry	9 982	5.42%	69 860	14.29%
3841	Automobile Industry	8 201	4.46%	101 689	8.06%
3220	Clothing	8 011	4.35%	121 715	6.58%
Total	**1998**	284 112	100.00%	4 213 566	6.74%
3831	Electric machinery, equipment and accessories	25 398	8.94%	294 452	8.63%
3814	Other metallic products	18 303	6.44%	136 391	13.42%
3822	Machinery and equipment	17 893	6.30%	83 895	21.33%
3560	Plastic products	17 500	6.16%	166 884	10.49%
3220	Clothing	14 203	5.00%	453 414	3.13%
3620	Glass	13 890	4.89%	46 185	30.07%
3841	Automobile Industry	13 854	4.88%	190 783	7.26%

Source: Own elaboration with data from: 1989 and 1999 *Censos Industriales* INEGI.

$$Y_{irt} = A_{irt}(.) f(L_{irt}) \qquad (1)$$

Where Y_{irt} is the urban manufacturing product of industry i, in the urban area r, at time t, A_{irt} is the technology specification and becomes the factor representing the agglomeration impact, and L_{irt} is the labor factor.

Incorporating (1) into a profit function, the following maximization problem is set up:

$$\pi_{irt} = A(.) f(L_{irt}) - S_{irt}L_{irt} \qquad (2)$$

Where S_{irt} are the wages in the local industry and L_{irt} is the amount of workers employed. Taking the first order conditions and determin-

Table 11. Monterrey: Electric Equipment and Machinery and Equipment Industries Disaggregated at 6-digit Level (1993)*

	Code	*Occupied Personnel*	%
Electric machinery, equipment and accessories	**3831**	21 954	100.00%
Electric engines and equipment	383101	4 266	19.43%
Welding equipment	383102	263	1.20%
Parts for automobile electric system	383103	8 480	38.63%
Electric bateries	383107	1 282	5.84%
Carbon and graphite electrodes	383108	784	3.57%
Electric materials	383109	3 113	14.18%
Light bulbs	383110	2 352	10.71%
Neon lights and luminous advertisments	383111	1 414	6.44%
Machinery and equipment	**3822**	10 876	14.47%
Non-electric engines	382201	13	0.12%
Assembly of trasportation machinery	382202	392	3.60%
Other machinery and equipment	382203	506	4.65%
Metallic parts for machinery and equipment	382204	5 296	48.69%
Pumps manufacturing and repair	382205	834	7.67%
Air conditioning and refrigeration equipment	382206	3 674	33.78%
Liquids and gas filters	382207	1 243	11.43%

Source: Own elaboration with data from the *1993 Censo Industrial*, INEGI.
* According to the Mexican Classification of Activities and Products.

ing the equilibrium of the manufacturing employment level, which equalizes the marginal value of the labor product with the local wage rate, the following expression is obtained:

$$A_{irt}(.)\, f'(L_{irt}) = S_{irt} \tag{3}$$

By solving for the marginal product of labor we obtain the following equation:

$$f'(L_{irt}) = \frac{S_{irt}}{A(.)} \tag{4}$$

In order to analyze the agglomeration effect on the urban manufacturing employment growth, it is convenient to separate the technological parameter $A(.)$ into three components:

i) The first component is related to the national technology level, and captures the changes in prices and technology in the economy as a whole. The expansion of technology can be represented in terms of growth rates:

$$\ln \frac{A_{n,t+1}}{A_{n,t}}$$

ii) The changes in urban technology growth are exogenous to the firms located in an urban area, and are determined by the effects of agglomeration on the industry performance. The impact of the external economies is dynamic and derives from the specialization within a particular urban industry (a_1),[1] the specialization of related urban industries (a_2),[2] the urban industry diversity (d)[3] and the plant size, as measured by the average number of workers (T). According to the theoretical concepts adopted in this study, the manufacturing agglomeration would turn into a regional externality, positively impacting urban manufacturing growth.

Formally, the growth of technology derived from regional externalities is presented as follows:

$$\ln\left(\frac{A_{r,t+1}}{A_{r,t}}\right) = h(a_{1ir}, a_{2ir}, d_{ir}, T_{ir})$$

iii) Finally, it is considered that urban agglomeration, in the larger cities of the northern border states, can potentially generate urbanization economies, which result from the proximity to the production factors market (F) and the urban demand for products (D). Therefore, the impact of parameter $A(.)$ is also a function of urban agglomeration and can be expressed as follows:

$$\ln\left(\frac{A_{u,t+1}}{A_{u,t}}\right) = U(F_{ir}, D_{ir})$$

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[1] The index of industry specialization is estimated using the classification of industries at the 4-digit level, according to the Mexican Classification of Activities and Products (CMAP).
[2] The index of specialization among related industries is estimated as the share of all the industries at 4 digits that made up the industry aggregated at the 2-digit level.
[3] The industrial diversity index weights the share of all the other industries at the 4-digit level on the industry aggregated at 2 digits.

The function representing the technology growth is denoted as follows

$$\ln\left(\frac{A_{t+1}}{A_t}\right) = \ln\left(\frac{A_{n,t+1}}{A_{n,t}}\right) + \ln\left(\frac{A_{r,t+1}}{A_{r,t}}\right) + \ln\left[\frac{A_{u,t+1}}{A_{u,t}}\right] \quad (5)$$

In order to set up an econometric specification, the production technology can be expressed in a Cobb Douglas function with only one factor (labor):

$$f(l) = Al^\beta \quad (6)$$

Where $\beta = 1 - \alpha$ and $0 < \alpha < 1$.

Obtaining the first order conditions:

$$A\beta l^{\beta-1} = S \quad (7)$$

Reordering and rewriting equation (7) in terms of rates of growth, combining it with (5) and (6) and applying a logarithmic transformation, equation (8) is obtained:

$$\alpha \ \ln\left(\frac{l_{t+1}}{l_t}\right) = -\ln\left(\frac{S_{t+1}}{S_t}\right) + \ln\left(\frac{A_{n,t+1}}{A_{n,t}}\right) + h(a_{1ir}, a_{2ir}, d_{ir}, T_{ir}) + u(F_{ir} D_{ir}) \quad (8)$$

Equation (8) can be specified using an empirical model to estimate the impact of agglomeration on manufacturing employment growth in the main cities of the northern border region of Mexico. The model assumes that employment growth has a negative relationship with wages and a positive relationship with the externalities.

IV. Econometric Specification to Estimate the Impact of Agglomeration

To empirically test the effect of urban manufacturing agglomeration, two log-linear econometric specifications were developed. The first one includes as the explanatory variables aglomeration indexes (proxys of externalities) and relative wages, and it is set up as follows:

$$\Delta\ln(L_{irt}/L_{rt}) = \alpha + \beta_1 \ln(RT_{irt}) + \beta_2 \ln(A_{1irt}) + \beta_3 \ln(A_{2irt}) + \beta_4 \ln(DI_{irt}) + \beta_5 \ln E + \beta_6 \ln r + e_{irt}$$

- The dependent variable is the relative employment growth in the urban manufacturing sector:

$$\Delta\ln(L_{irt}/L_{rt}) = [\ln(L_{irS}) - \ln(L_{irt})] - [\ln(L_{iS}) - \ln(L_{it})],$$

where i and r represent the manufacturing industry and the urban region, respectively, s is the final period and t is the initial period.

- RT is the annual remuneration per worker in the industry i for the urban areas j during the period t, weighted by the annual remuneration for the industry at a national level j during the period t:

$$RT_{ijt} = (R_{ijt}/L_{ijt})/(R_{it}/L_{it})$$

- A_1 is the index of industry specialization and is defined at a 4-digit level according to the Mexican Classification of Products and Activities (CMAP). The index is constructed as follows:

$$A_{1irt} = (L_{irt}/L_{it})/(L_{it}/L_t)$$

This index measures the level of specialization of an industry within a city, relative to that industry specialization at the national level.
- A_2 represents the agglomeration of related industries. These industries share the classification at 2-digit level according to CMAP.

$$A_{2irt} = (L_{ikt}/L_{irt})/(L_{kt}/L_{it}),$$

where k represents the aggregated industry at two digits.

This variable is a proxy to estimate the relationship between suppliers and buyers of inputs of the industries at the 4-digit level.

- DI is the diversification index of the manufacturing industry i in the urban area r during the period t. It also constructed at the 4-digit level. This index of diversification is given by $\Sigma_{i \neq r}(L_{ikt}/L_{rt})^2$, but in this econometric specification is weighted by the same index at national level aggregation:

$$DI_{irt} = \Sigma_{i \neq r}(L_{irt}/L_{rt})^2/\Sigma_{i \neq r}(L_{it}/L_t)^2$$

This index is used to measure the degree of concentration or diversity within industries at the 4-digit level.

- Finally, the total level of employment E and the total amount of earned wages R, for the manufacturing industries in the base year, represent the control variables. In the case of the first variable, it is assumed that if external economies are located in the urban areas, a greater level of initial employment (labor agglomeration) in the urban industries would result in a higher rate of growth in the manufacturing industries at the 4-digit level. On the other hand, the model considers that the demand for manufacturing workers will shift from the higher wage urban areas to the areas with lower wages, thereby increasing the manufacturing employment growth of the northern border cities.
- e_{irt} is the error term, and it is assumed to present the following form:

$$e_{irt} = c_i + \gamma_i + \eta_i$$

where c_i is the fixed effect by urban area i, γ_t is the fixed effect for year t and η_i is the independent and random variable with mean zero and a variance σ^2.

The second model, besides including industrial agglomeration measures, incorporates a variable representing the externalities derived from urban agglomeration. The objective is to find out whether or not urban agglomeration economies are present in the manufacturing sector of the northern border cities. The proxy of urban agglomeration used in the study is the urban population. The model is set up as follows:

$$\Delta\ln(L_{irt}/L_{rt}) = \alpha + \beta_1\ln(RT_{irt}) + \beta_2\ln(A_{1irt}) + \beta_3\ln(A_{2irt}) + \beta_4\ln(DI_{irt}) + \beta_5\ln E + \beta_6\ln r + \beta_7\ln EU + e_{irt}$$

- *EU* are the urban economies, which imply a more efficient use of available resources in the cities, due to the existence of pooled labor markets, and a larger service sector.

IV.1. Database

The database consists of 54 manufacturing industries at the 4-digit level, as published in the Industrial Census of 1994 and 1999 by INEGI. This industry classification was applied to northern region cities: Tijuana, Ciudad Juárez, Hermosillo, Chihuahua, Torreón, Saltillo, Monterrey, Nuevo Laredo and Matamoros. The database for the urban manufacturing industries was constructed by integrating manufacturing information by "municipios" (counties), according to the urban and metropolitan classification by INEGI, and Population Census of 1990.

V. Econometric Results

The first econometric model was applied to a cross sectional database for the 1988-1993 period. The empirical findings derived from the different regressions that were estimated show that, for this period, the statistically significant coefficients were the ones related to the variables of specialization within the industry (4 digits), the specialization among industries (sharing the classification at 2 digits) and the industrial diversity. The coefficients of specialization within the industry and industrial diversity showed an inverse effect with respect to manufacturing employment growth. On the other hand, the coefficient of the specialization among industries exhibited a positive sign (see Table 12). The regressions were based on a heteroskedasticity-consistent standard errors and covariance matrix, developed by White (1980).

For the period encompassing the years from 1993 to 1998, which includes the NAFTA period, the econometric model showed the same relationship between manufacturing employment and the variables representing industrial agglomeration. However, one important change in the relationship between the dependent and the explanatory variables occurred during this period (see Table 13). The variation has to do with the coefficient of the initial total employment in 1988. According to the results, the manufacturing employment growth was positively related to the coefficient of initial employment, although it was also statistically insignificant. According to the assumptions of the econometric research, when there is a large level of manufacturing employment in an urban area, the manufacturing employment might

Table 12. Northern Border Cities. Dependent Variable: Relative Employment Growth, 1988-1993

Variable	Coef.*	t-Stat.	Coef.	t-Stat.	Coef.	t-Stat.	Coef.	t-Stat.	Coef.	t-Stat.	Coef.	t-Stat.
Agglomeration 1	-0.22	-3.73	-0.21	-3.72	-0.21	-3.76	-0.20	-0.81	-0.18	-3.59	-0.27	-6.23
Agglomeration 2	0.12	1.81	0.12	1.83	0.12	1.83	0.12	-3.68	0.13	1.93		
Diversity	-0.09	-0.96	-0.09	-1.02	-0.09	-1.16	-0.09	1.81				
Relative Wages	0.10	0.86	0.11	0.90	0.11	0.90						
Employment 1988	0.00	-0.68	0.00	0.67								
Total Wages 1988	0.00	0.91										
R²	0.16		0.16		0.16		0.16		0.16		0.15	
Adjusted R²	0.15		0.15		0.15		0.15		0.15		0.15	
Durbin-Watson	1.89		1.89		1.89		1.90		1.90		1.88	

* White Heteroskedasticity–Consistent Standard Errors and Covariance.

increase due to the effects of agglomeration of labor. Therefore, for this period, the existence of large manufacturing employment probably was an important factor for the development of pooled labor markets.

A Chow breakpoint was calculated, to evaluate the possibility of structural change in the relationship of the explanatory and dependent variables for the 2 periods studied. The results reject the hypothesis of stability. Therefore, the effects of agglomeration economies, represented by the specialization among industries parameter should be estimated separately, in order to capture the differences in the 2 periods considered.[4]

Finally, a regression model including the urban population of the northern border cities was estimated. The econometric findings showed a very low value of the population coefficient, which showed a positive and statistically significant relationship between this coefficient and employment growth (see Table 13). This empirical evidence suggests that urban agglomeration, measured by the proxy of population, has a positive but very small impact on manufacturing employment growth.

VI. Concluding Remarks

The present research intended to empirically test the effect of manufacturing agglomeration for the most important northern border cities of Mexico. The econometric specification included two control variables: total employment and total wages for the initial year of the periods analyzed. It also incorporated the level of population of the cities as a proxy of urban agglomeration, in order to evaluate the impact of this type of agglomeration on urban manufacturing growth.

The analysis of the cities within the northern border region shows that, by the end of the 1980s, Tijuana and Ciudad Juárez developed industries with a large share of the national manufacturing employment. During the 1990s, rapid employment growth is experienced not only in Tijuana and Ciudad Juárez, but also in medium sized northern border region cities such as Nuevo Laredo, Saltillo, Matamoros

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[4] The null hypothesis of stability was rejected. The *F*-Test exhibited an *F*-statistic of 2.95 while the critical values of the *F*-distribution were 1.83 at a 5% significance level and 2.41 at a 1% significance level.

Table 13. Northern Border Cities: Urban Agglomeration and Relative Employment Growth, 1993-998

Variable	Coef.*	t–Stat.	Coef.	t–Stat.	Coef.	t–Stat.	Coef.	t–Stat.	Coef.	t–Stat.	Coef.	t–Stat.	Coef.	t–Stat.
Agglomeration 1	-0.13	-1.84	-0.13	-1.94	-0.11	-1.53	-0.10	-1.63	-0.11	-1.98	-0.11	-2.53	-0.24	-5.63
Agglomeration 2	0.18	2.76	0.18	2.76	0.19	2.92	0.18	2.69	0.17	2.39	0.17	2.61		
Diversity	-0.11	-0.10	0.11	1.112	0.10	0.92	0.10	1.01	0.02	0.24				
Population	0.00	0.47	0.00	0.84	0.00	1.34	0.00	1.58						
Relative Wages	0.08	0.81	0.09	0.91	0.08	0.76								
Employment 1993	0.00	1.023	0.00	1.02										
Total Wages 1993	0.00	0.84												
R^2	0.19		0.19		0.18		0.18		0.18		0.18		0.16	
Adjusted R^2	0.17		0.17		0.17		0.17		0.17		0.17		0.16	
Durbin-Watson	2.04		2.03		2.01		2.02		2.01		2.01		1.99	

* White Heteroskedasticity-Consistent Standard Errors and Covariance.

and Hermosillo. As a result, those urban areas experienced urban and industrial agglomeration. According to the model developed in this paper, the effects of such agglomeration were the following:

- The firms with the fastest growth in the most important northern border cities were located within the following industries: electric machinery equipment and accessories, electronic equipment, radio and television assembly, and textiles. For the case of Monterrey, the most dynamic industries were metallic products, electric machinery, equipment and accessories, automobiles and the glass industry.
- The econometric findings showed that the coefficient of specialization among industries partially explained manufacturing employment growth in the northern border cities during the two periods analyzed. It is important to stress that, in the 1993-1998 period the dependent variable was positively affected by the level of total employment in 1993.

Therefore, the empirical results suggest that trade liberalization and the integration of the Mexican with the US economies has shifted the manufacturing employment dynamics from the large cities of Central Mexico towards cities of the northern border states. The expansion of the manufacturing industry in the northern region has been accompanied by the rapid development of manufacturing firms under the maquiladora regime. This type of industry was predominantly developed by foreign investors and, as a result, developed manufacturing and urban agglomeration in the urban centers of that region.

The econometric results exhibited evidence of the impact of manufacturing and urban agglomeration economies on manufacturing employment growth. The industry agglomeration is related to the backward-forward linkages between firms and factors of production within the urban centers. The impact of agglomeration was very small but positive, showing that the urban expansion is probably developing pooled labor markets in some of the cities of the northern border.

The implications of the empirical evidence for public policy are directly related to the characteristics of manufacturing growth in the northern cities of Mexico. In the first place, a plausible normative statement would be directly related to the increasing divergence in the rates of growth of the most important manufacturing cities and the increasing pressure that urban and manufacturing growth is putting on in-

frastructure and public capital. As a result, it becomes necessary that the government develop the conditions to support steady manufacturing growth in the region.

Additionally, the specialization of particular industries, and the effect of this on the development of pooled labor markets in the most important cities of the region, has implications for educational policy. In that sense, both local and federal governments should develop coordinated efforts to establish educational programs to reinforce the labor skills demanded by the industries of those cities.

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