Investigaciones Regionales

The geographic concentration in Mexican manufacturing industries, an account of patterns, dynamics and explanations: 1988-2003

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ABSTRACT: This paper presents an examination of regional concentration levels of individual industries in the Mexican manufacturing sector and its determinants. The shifts after NAFTA are particularly weighed up. We employ state level data of manufacturing output and employment (1988-2003). The data reveals that industries have become, on average, more dispersed in terms of both production and employment. However among the most concentrated industries are those which are highly linked to international markets. The concentrated, concentrating and largest industries tend to locate in traditional industrial regions, in the north but increasingly more in the Bajio. The regression analysis for the determinants of concentration shows consistency with a number of predictions such as the significance of economies of scale, wages, exports and transport costs, which indicates that international trade plays a role in concentration profiles of industries.

JEL Classification: R10, R12, 018.

Keywords: geographic concentration, localisation, trade, regional economics, Mexico.

La concentración geográfica de las industrias manufactureras de México, un recuento de los patrones, su dinámica y sus explicaciones: 1988-2003

RESUMEN: Este artículo presenta un análisis de la concentración geográfica en las industrias manufactureras en México y de sus determinantes. Los cambios a partir del TLCAN son de especial interés. Usamos información a nivel estatal del empleo y el producto manufacturero (1988-2003). Los datos muestran que en promedio las industrias de este sector han sufrido un proceso de dispersión del empleo y producto en ese periodo. Sin embargo, entre las industrias mas concentradas geo-

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gráficamente están algunas altamente integradas a los mercados internacionales. Las industrias mas concentradas, las que se están concentrando y las más grandes tienden a ubicarse en centros industriales tradicionales, en el norte pero crecientemente más en el Bajío. El análisis de regresión muestra consistencia con una serie de predicciones teóricas tales como la importancia de las economías de escala, los salarios, exportaciones y costos de transporte, lo cual señala que el comercio internacional influye de alguna manera en la concentración geográfica de algunas industrias.

Clasificación JEL: R10, R12, 018.

Palabras clave: concentración geográfica, localización, comercio, economía regional, México.

1. Introduction

Old and recent literature on regional economics highlights the significance of studying the geographical aspects of the economy because of its link with urbanisation processes, growth and development. More recently the role of economic globalisation in shaping the spatial organisation of economic activities within countries is regarded as significant. Mexico has been largely considered a good case to study since it carried out an intense process of opening up of its economy since the early 1980's. A first stage of this consisted of unilateral and multilateral liberalisation whereas a Free Trade Agreement within the North American region entered into effect in 1994. In researching Mexico's economic geography it has been frequently assumed that protectionist policies led to an increasing spatial agglomeration of economic activities provided that, in an economy closed to external trade, firms tended to locate near the main domestic markets -usually the capital city. Yet processes of trade liberalisation and integration tend to modify the spatial patterns of the economy. Early literature called attention to the likely geographic shifts that would be a consequence of a changing regime. There is the typical idea of an adjustment from a centralised industrial core to dispersed northern sites as a consequence of the transition from import substitution to export-oriented industrialisation. By and large previous research such as that by Krugman and Livas (1996), Hanson (1998), Katz (1998), Chamboux-Leroux (2001), Sanchez-Reaza and Jordaan (2002), Corona (2003), Decuir-Viruez (2003), Dussel (2003), Garza (2003), Sobrino (2003) and Sanchez-Reaza and Jordaan (2004), find that a northward relocation of manufacturing characterised the geographic adjustment which followed the adoption of an extensive program of economic and trade liberalisation. Whereas most of this work looks at the whole economy or the total manufacturing sector we put forward the idea that indeed the Mexican economy has undergone a process of regional reallocation of production and labour, particularly within manufacturing, however such a process presumably being much differentiated across industries.

The geography of disaggregated industries has received less attention and has been approached from different lines of attack. Often the focus is on explaining

localization rather than concentration as such. In this line of work we find studies for specific cases such as the automotive industry (Wong-Gonzalez, 1991; Ramírez, 1998; Carrillo, 2000; and Unger and Chico, 2002). Some research has dealt with the geographic concentration of manufacturing industries as a variable to explain, for instance, productivity or efficiency (Bannister and Stolp, 1995; Grether, 1999). Mendoza and Perez (2007), on the other hand, deal with the regional shift of manufacturing by considering the regional growth in employment shares across industries between 1994 and 2004. Davila (2004) provides a useful reference of geographic concentration of industries in the period 1980-1998 and evaluates some of the predictions about the effect of trade liberalisation on concentration and location of manufacturing employment. By looking at the locational Gini index he finds increasing average dispersion of employment between 1980 and 1993 and a mild increase in concentration after NAFTA (1993-1998). On average manufacturing employment dispersed.

Over the whole period the number of dispersing industries predominates leading to average dispersion. The industry with the largest increase in geographic concentration is Footwear whereas the rest of those industries that showed increasing concentration belong mostly to the Metal products, machinery and equipment industry. On the other hand, the least concentrated industry is Tortillas and nixtamal milling while the most concentrated sector changes over time: oil processing in 1980, basic petrochemical in 1988 and electronic equipment in 1998. Nevertheless, none of these studies attempt to establish the factors that explain the variation in geographic concentration across Mexican industries.

For North America Vogiatzoglou (2006) address the question of how integration affects the spatial structure of economic activities across NAFTA countries by investigating the extent to which concentration varies across industries and the effect of relevant industry characteristics on concentration levels. This study reveals important facts on the economic geography of manufacturing but between rather than within NAFTA countries. This paper expects to contribute to similar studies by allowing for industry differences in the spatial adjustment to liberalisation and to analyse the geography of Mexican manufacturing industries by addressing the following aspects:

a) The extent to which manufacturing industries concentrate and locate.
b) The differences in concentration across industries.
c) The dynamics of geographical concentration over time.
d) The determinants of cross-industrial variation in geographic concentration.

This allows us arriving at a number of relevant empirical facts that are informative about the geography of industries within Mexico and the impact of economic reforms such as liberalisation and integration. First we present a conceptual and theoretical review relevant to this work. Then a description of patterns and changes in geographic concentration and localisation is given. Following this there is a review of a number of characteristics across industries which presumably affect concentration. The relationship between industry characteristics and geographic concentration is looked at by carrying out multivariate analysis of a reduced form specification.

2.   The concept and the theory of geographic concentration

Geographical concentration is a concept used to account for the spatial distribution of sectors at a disaggregated level as opposed to the idea of *agglomeration* of the whole economy or aggregated sectors such as manufacturing or services, and also different from *location* that indicates «where» rather than «how much» industries are situated. Midelfart-Knarvik *et al.* (2000) point out that, «*... there is no single* [location] *process driving all industries in the same direction»* (p. 46). Individual industries have their particular features that might influence the extent to which they concentrate in space and where they locate. That is, the propensity to group together in space is not the same for different types of economic activities. On the other hand, national economies often rely on a number of specific economic sectors more than they rely on others such that the extent to which the biggest industries concentrate have different regional impacts.

There is also the distinction between relative and absolute concentration. Relative concentration refers to an industry whose geographical distribution differs significantly from the distribution of total production. Absolute concentration appears when the total production of an industry or sector of activity is distributed highly unevenly between regions. Absolute concentration reflects those predictions dictated by the new trade theory and the GE approach, which suggest the presence of economies of scale and vertical linkages as determinants of industries' geographic distribution, while relative concentration indicates the existence of elements of traditional trade theory and is strictly connected to the concept of comparative advantage (Gordo *et al.,* 2003; Cutrini, 2006).

Approaches such as the New Economic Geography theory (NEG) has opened a focus on these issues responding to the need for evaluating the industry-specific spatial landscape. Fujita *et al.* (2001) develop a model based on the basic core-periphery structure *a la* Krugman which enables them to answer the question «what manufacturing will be concentrated where». Further efforts to address geographical concentration have not varied much with respect to this basic model. Certainly, studies have been predominantly empirical-oriented. Head and Mayer (2003) provide a complete survey of the research on the geographic concentration of industries. In their opinion, most of the empirical work has largely consisted of reduced-form approaches to assess the theoretical hypotheses and even though existing empirical analyses still remain at the stage of identifying spatial changes in industries these attempts are useful in that they provide evidence of the stylised facts. Combes and Overman (2003) discriminate between studies that are descriptive in nature, which they call «area-based descriptive work» or «the first generation of area-based studies», and explanatory approaches that have more theoretical grounds. Although these authors regard most existing empirical work on the concentration of industries as imperfect, they acknowledge the usefulness of their outcomes.

The effects of increasing liberalisation and economic integration on the spatial concentration of industries may differ and this adds current meaning to the empiri-

cal analysis of geographic concentration. Therefore attention has been paid to the question of whether integration processes in Europe, North America and Asia lead to more or less spatially concentrated industries (Haaland *et al.,* 1998; Midelfart-Knarvik *et al.,* 2000; Traistaru *et al.,* 2002; Brülhart and Traeger, 2003; Combes and Overman, 2003; Ge, 2003; Gordo *et al.,* 2003; Overma and Winters, 2003; Park *et al.,* 2004; and Vogiatzoglou, 2006). With reference to the effect of liberalisation according to the existing literature in a closed economy sectors with low economies of scale and high transport costs will tend to disperse; those with high economies of scale and low transport costs will agglomerate. Therefore liberalisation might have different effects on geographical concentration depending on industry characteristics which are relevant.

For Europe empirical work on geographic concentration is presented by Traistaru *et al.* (2002) in a review of the economic geography of a number of accession countries based on patterns of regional specialisation and geographic concentration. With a similar approach, Gordo *et al.* (2003) focus on the relationship between the European integration and changes in countries' economic spatial structure. Similarly, Brülhart and Traeger (2003) look for empirical «well-founded facts» and in so doing provide a comprehensive account of sectoral concentration patterns across western European regions. Overall results indicate decreasing average concentration of manufacturing activities but in this case the process of European integration seems not to have had striking consequences for the geography of production. Concentration is observed only in low-tech and labour-intensive industries. With a similar focus but a different methodology, Midelfart-Knarvik *et al.* (2000) describe industrial location, countries' economic structure and spatial concentration of industries; they compare the cases of the EU and the US and seek to identify the underlying determinants of spatial patterns. Usually the main forces taken into account when searching for the determinants of concentration of industries are industry-specific characteristics mainly related to endowments, technology, industrial linkages, economies of scale and transaction costs. Haaland *et al.* (1998) carry out a cross-sectoral analysis to explain relative and absolute concentration and the impact of European integration. Ge (2003) undertake an analogous analysis for China and the effects of external trade on its economic geography specifically on regional inequality patterns.

3. Patterns and Dynamics of Geographic Concentration and Localisation, 1988-2003

Most of past studies on the location of the Mexican economy have documented the locational shifts and a geographic dispersal of manufacturing production, employment and/or population at the aggregate level. They find that relocation and dispersion of manufacturing took place as a consequence of trade liberalisation (1980s) and economic integration (1990s). These transformed the optimal location choice of manufacturing firms and promoted dispersion from Distrito Federal's manufacturing

base towards the border with the U.S. and the so called Bajío states. This is a broad depiction of the geographic rearrangements happening within the Mexican context and such a story has been often the basis of the assertion that an all-embracing dispersion of manufacturing and a reduction in regional disparities are actual facts. However the regional adjustment of manufacturing has taken the form of a mild declining agglomeration and noteworthy location shifts at the state level but this being a long-term tendency. Agglomeration has declined over time but dispersion has been minimal and began prior to the 1980s. Yet there is more than one account at the intra-sector level. Industries have particular production and market characteristics and so one finds that geographic concentration tends to be strongly activity-specific. Similarly the effect that globalisation forces have on each industry differs. Its impact is expected to be stronger in those large and internationally competitive sectors which are able to insert in foreign markets; the effect on other industries possibly being more negative, inertial or null. In fact, trade liberalisation and integration are likely to have promoted a direct geographical rearrangement of only a limited number of manufacturing industries.

Hence it is important to look at the geographical patterns of individual industries for further insights into the role of geographic concentration of distinct industries in determining the geography of overall manufacturing. Hereafter we deal with this issue. The Herfindahl, Krugman, and Gini indices are among the most common measures employed in empirical research to assess concentration; yet a larger number and variety of indices have been developed. Ellison and Glaeser (1997) and Maurel and Sédillot (1999), for example, propose more informative indices which in addition control for the effect of plant-size. Our selection of indices is influenced significantly by the availability of geographic data. As the calculation of Ellison and Glaeser, and Maurel and Sédillot indicators requires data at the plant level this study is based on the Herfindahl Index and a version of the Gini index which account for absolute geographic concentration even though the use of these involves some advantages and drawbacks [1]. Two measures are considered to verify somehow the robustness of results and its equivalence with previous studies. Our focal indicator is output but in the descriptive part we look at both output and employment concentration to see how patterns vary across 54 four-digit industries employing data from the 1989, 1994, 1999 and 2004 Economic Censuses carried out by INEGI [2]. The basic geographical units of analysis are the thirty two Mexican states.

The *Herfindahl index* (HI) shows to what extent an economic activity is distributed across a number of geographic units. The maximum value it takes is 1, indica-

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[1] The HI uses all the information across geographic units but puts great emphasis on the largest shares (Aiginger and Davies, 2004; Cutrini, 2006). The problem when using the GI is that it places higher importance on changes in the middle part of the distribution (Cutrini, 2006). Besides the two concentration indices do not allow just to add up changes in individual industries or regions to give an overall change (Aiginger and Davies, 2004).

[2] In order to make the information comparable over time we reclassified data from the 2004 census, which is presented under the North American industrial classification (NAICS), into the Mexican classification (CMAP). Thus the computed indices for 2003 may involve some measurement errors.

ting a high degree of concentration; alternatively, values close to 1/N (where N is the number of regions) reflect a high degree of dispersion of industries across states:

$$HERF_k = \sum_{n=1}^{N} \left[\frac{Y_k^i}{Y_k^{national}} \right]^2$$

Where, Y = gross product (alternatively value-added or employment); k = industry; N = number of regionns; i = regions.

Gordo *et al.* (2003) propose a Gini index (GI) to measure absolute concentration. It can take values between 0 and 1:

$$GINI_k = \left(\frac{1}{2N^2} \right)\left(\frac{1}{\mu} \right)\sum_{i=1}^{N}\sum_{j=1}^{N} \left| \left(\frac{Y_k^i}{Y_k^{National}} \right) - \left(\frac{Y_k^j}{Y_k^{National}} \right) \right|$$

Where μ = average participation.

The Herfindahl index confirms the results of the Gini index in two aspects: a) average dispersion of industries has taken place after formal North American integration (1993-2003) but dispersion was in motion already by the time of NAFTA (1988-1993); generally, output concentrates more than employment, although for a number of individual industries the opposite holds (Table 1)[3]. The HI shows average dispersion of employment and output between 1988 and 1993 as found by Davila (2004). Yet, contrasting with GI, there is further dispersion between and 1993-1998 probably because mainly states with largest shares decreased their participation while average shares increased. From 1998 to 2003 there was further dispersion according to GI and HI.

Table 1. Average Concentration of Industries

	1988		1993		1998		2003	
	Y	L	Y	L	Y	L	Y	L
Herfindahl Index	0.20	0.16	0.18	0.14	0.17	0.13	0.16	0.12
Gini Index	0.78	0.72	0.75	0.69	0.75	0.68	0.73	0.67

Source: Own calculations with data from INEGI.
Y: Output.
L: Employment.

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[3] The Spearman's rank correlation between the rankings of industries based on the Gini and the Herfindahl indices is around 0.90 for all periods with a statistical significance at the 1% level.

The HI indicates that the least concentrated industry in terms of output and employment has been Tortillas and nixtamal milling. This activity may be following the distribution of demand since it produces a typical perishable food which is part of the basic diet of the Mexicans. It consists typically of numerous micro or small businesses serving the area around them. In 1988 the Pharmaceutical sector appeared to be the most concentrated industry in terms of both output and employment. From 1993 onwards the Machinery and equipment for offices and informatics industry became the most concentrated in terms of output. This is a technology-intensive industry, among the ten largest industries and one of growing relevance. It is mainly made up of exporting plants belonging to transnational companies, some of which operate under the maquiladora regime, and is one important recipient of FDI (Mendoza, 2003). Even though Pharmaceuticals manufacturing was still the most concentrated in terms of employment in 1993, the Footwear sector became the most concentrated afterwards (Table 2).

Table 2.   Most and Least Concentrated Industries, Herfindahl Index (1988-2003)

	1988		*1993*		*1998*		*2003*	
	Y	L	Y	L	Y	L	Y	L
LC	Tort (0.07)	Tort (0.06)	Tort (0.05)	Tort (0.05)	Bev (0.06)	Tort (0.05)	Tort (0.06)	Tort (0.05)
MC	Pharm (0.45)	Pharm (0.39)	MEOI (0.57)	Pharm (0.40)	MEOI (0.73)	Footwear (0.40)	MEOI (0.59)	Footwear (0.45)

Source: Own calculations.
LC: Least concentrated.
MC: Most concentrated.
Pharm: Pharmaceuticals.
Tort: Tortillas.
Bev: Beverages.
MEOI: Machinery and equipment for offices and informatics.

Overall the least concentrated industry is the same for both indices. Yet in the case of the Gini index the results indicates that Basic petrochemical is the most concentrated industry in terms of employment in 1988 and 1993 and Synthetic and artificial fibres manufacturing in 1998 and 2003 whereas in terms of output Basic petrochemical is the most concentrated in 1993. For the most part Davila's results are confirmed (Table 3).

Independently of the average trend each industry follows its own tendency which also affects their rank position. We follow a procedure similar to that of Midelfart-Knarvik *et al.* (2000) to check changes in the ranking of industries between 1988 and 2003. We also look at the variation in the geographic concentration of each industry over time. Industries were divided into five groups according to concentration levels and rank changes: the most concentrated industries that remained so (CC), the most concentrated industries that left the group (CD), the most dispersed industries which remained so (DD), the most dispersed industries that left the group (DC) and the

Table 3.   Most and Least Concentrated Industries, Gini Index (1988-2003)

	1988		1993		1998		2003	
	Y	L	Y	L	Y	L	Y	L
LC	Tort (0.50)	Tort (0.45)	Tort (0.48)	Tort (0.41)	Tort (0.48)	Tort (0.42)	Tort (0.48)	Tort (0.42)
MC	Pharm (0.91)	Basic petroche-mical (0.90)	Basic petroche-mical (0.93)	Basic petroche-mical (0.89)	MEOI (0.93)	Synthetic or artificial fibres (0.91)	MEOI (0.93)	Synthetic or artificial fibres (0.91)

Source: Own calculations.

remaining industries. By categorising industries in this fashion we identify the rank position of industries at an initial point in time as well as changes in their ranking relative to the rest. Accordingly in 2003 there were twelve CC industries, eleven DD industries, six CD industries and seven DC industries (Table 4).

Table 4.   Concentrated and Concentrating Industries, 1988-2003

Most concentrated industries that have remained so (CC)	*Most concentrated industries are no longer so (CD)*
1. Pharmaceuticals (D) 2. MEOI (C) 3. Publishing and printing (D) 4. Chemical products (D) 5. Footwear (C) 6. Basic petrochemical (D) 7. Instruments and precision equipment (D) 8. Leather and fur products (C) 9. Glass and glass products (D) 10. Synthetic or artificial fibres (C) 11. Fibre, yarn, and thread mills (D) 12. Tobacco products (C)	1. Ceramics and pottery (D) 2. Other manufacturing industries (D) 3. Apparel (D) 4. Cocoa, chocolate and sugar confectionery (D) 5. Coke (D) 6. Metal furniture (D)
Most dispersed industries that are no longer so (DC)	*Most dispersed industries that have remained so (DD)*
1. Oil processing (C) 2. Machinery and equipment for generic purposes (C) 3. Edible oils and fats (C) 4. Machinery and equipment for specific purposes (C) 5. Automotive industry (C) 6. Basic chemicals (C) 7. Processing and preserving of foods (C)	1. Fabric mills (D) 2. Wood products and carpentry (D) 3. Metallic frames, tanks and industrial boilers (D) 4. Meat products (D) 5. Wooden containers and other wood products and cork (D) 6. Beverages (D) 7. Prepared animal feeds (D) 8. Dairy products (C) 9. Cement, lime and plaster (D) 10. Grain mill products, starches and cereals (C) 11. Tortillas and nixtamal milling (D)

Residual group (RG)	
1. Textile furnishings mills (D) 2. Rubber industry (D) 3. Plastic products (D) 4. Clay for the construction industry (D) 5. Other metallic products (except machinery and equipment) (D) 6. Sugar (D) 7. Pulp, paper and paper products (D) 8. Furniture mostly of wood (D) 9. Metallic pieces: smelting and moulding (D)	10. Basic metals: except iron and steel (C) 11. Bread (D) 12. Machinery, equipment and electric accessories (C) 13. Textile and fabric finishing and fabric coating mills (D) 14. Electronic equipment (C) 15. Devices and accessories for domestic use: except electronics (D) 16. Basic metals: iron and steel (C) 17. Transport equipment and parts: except autos and trucks (D) 18. Other human feed products (D)

Source: Author.

Industries within the CC group did not necessarily increase their absolute level of concentration; actually only four industries in this category increased their geographic concentration. The number of dispersing industries dominates: on the whole eighteen industries increased their absolute concentration while thirty six dispersed. Most of the concentrating industries belong or are related to the Food processing, Metals manufacturing, and Machinery and equipment sectors.

There is a tendency for concentrated industries to locate in the longstanding main industrial centres, namely, Distrito Federal, Estado de Mexico, Jalisco and Nuevo Leon. For some industries these locations, especially Distrito Federal and Estado de Mexico, tend to lose relevance as production centres. For instance, in the Pharmaceuticals industry relocation took place towards Jalisco and Morelos, reducing the joint share of Distrito Federal and Estado de Mexico. Yet this sector remained among the most concentrated industries, 94% of its gross output was located in four states. The Machinery and equipment for offices and informatics manufacturing industry has developed into a highly concentrated sector. While in 1988 it was located in Chihuahua and Jalisco in 2003 there was a movement towards Nuevo Leon. This relocation is in the direction of a traditional centre which is favoured by its location in Mexico's northern border. In 1988 Publishing, printing and related industries was concentrated in Distrito Federal, Estado de Mexico and Nuevo Leon while in 2003 the decline of the first two regions is rather obvious. The Footwear sector moved from Jalisco and Estado de Mexico towards Guanajuato which reached a strong position generating almost three-quarters of output in 2003 (Table 5).

Estado de Mexico has been exerting a pull on some of the industries with increasing concentration levels (Grain mill products, starches and cereals; Edible oils; Food processing; and Dairy products). Jalisco has gained increased shares in the production of tobacco. The production of Machinery for generic or specific purposes has located mainly in Distrito Federal, Estado de Mexico and Nuevo Leon but it increasingly prefers the latter. Nuevo Leon as well as San Luis Potosí have also benefited from concentration of the Iron and steel industry. The Basic chemical sector is tending to locate

Table 5. Location of Concentrated Industries

Industry	1988	2003
Pharmaceuticals	Estado de Mexico (20%) Distrito Federal (64%)	Estado de Mexico (18%) Distrito Federal (57%) Jalisco (7%) Morelos (12%)
MEOI	Chihuahua (11%) Jalisco (63%)	Jalisco (75%) Nuevo Leon (12%)
Footwear	Jalisco (22%) Estado de Mexico (14%) Guanajuato (49%)	Jalisco (14%) Estado de Mexico (5%) Guanajuato (72%)
Publishing and printing	Estado de Mexico (9%) Distrito Federal (58%) Nuevo Leon (9%)	Estado de Mexico (8%) Distrito Federal (49%) Nuevo Leon (9%)

Source: Own calculations.

in Estado de Mexico and Tamaulipas whereas Guanajuato has seen a considerable rise in its share of Leather and fur production. Thus location movements in the concentrating industries show only a few new locations. In most instances they tend to concentrate in Estado de Mexico, Jalisco, Guanajuato, Tamaulipas and Nuevo Leon.

4. Concentration and the Size of Industries: Weighted Concentration Index

The extent to which the geographic concentration of industries affects the regional distribution of the whole of the manufacturing depends not only on the number of industries concentrating or on the simple average concentration but also on the relative size of industries. Aiginger and Davies (2004) refers to the average weighted concentration as «typical or average concentration». This is defined as weighted averages of concentration with the weights being the industry shares of aggregate manufacturing. Table 6 shows the largest and the smallest industries in 2002 in terms of manufacturing output, according to the annual industrial survey (INEGI, 2002). One sector, the automotive industry generated nearly a quarter of total gross output. Approximately another quarter was produced by other four industries. Compared to 1994 the top five industries, with the exception of iron and steel, were of growing economic relevance in particular the automotive industry (from 17% to 22%). In contrast, thirty five industries went through decreases of various extents in their participation on manufacturing over the same period.

As with the simple concentration we observe dispersion between 1988 and 2003 being this a smooth tendency at least on a five-year basis comparison (Table 7).

Although a combination of high concentration and large size makes industries major drivers of geographic changes, the biggest industries dominate in the ranking

Table 6.   The Largest and Smallest Industries in 2002

Largest Industries	*Smallest Industries*
1. Automotive industry (22%) 2. Beverage manufacturing (7.5%) 3. Chemical products (5%) 4. Manufacture of basic metals, iron and steel (5%) 5. Pharmaceuticals manufacturing (5%)	1. Transport equipment and parts/except automobiles and trucks (0.2%) 2. Metallic pieces melting and moulding (0.2%) 3. Products of wood and carpentry: except furniture manufacturing (0.2%) 4. Fibre, yarn, and thread mills (0.05%) 5. Wooden containers and other wood products and cork (0.03%)

Source: INEGI. Annual Industrial Survey.

Table 7.   Average Weighted Concentration

	1988		1993		1998		2003	
	Y	L	Y	L	Y	L	Y	L
Herfindahl	0.333	0.340	0.327	0.311	0.320	0.391	0.307	0.276
Gini	1.423	1.308	1.386	1.228	1.374	1.211	1.364	1.193

Source: Own calculations.

of weighted concentration more by reason of their size while they tend to have medium levels of concentration. In 1988 the top ten industries according to the weighted concentration were: Automotive, Basic petrochemical, Chemical products, Pharmaceuticals, Oil processing, Iron and steel, Publishing and printing, Paper products, Machinery, equipment and electronic accessories, and Basic chemicals. Overall no big changes took place in the ranking between 1988 and 2003 at the top of the weighted concentration rank. Yet Machinery and equipment for offices and informatics is an outstanding case which became an important driver of geographic changes in overall manufacturing due to its exceptional growth in economic relevance and concentration. At the bottom of the ranking there are industries that are generally dispersed and small such as Tortillas; Wooden products; devices for domestic use; Prepared animal feeds, and the like; the exception is Ceramics and pottery manufacturing, which has been a very concentrated industry.

Table 8 shows the location of industries with the highest weighted concentration. In 1998 the automotive industry was located mainly in Estado de Mexico, Coahuila and Distrito Federal, which together accounted for more than a half of the industry's output, while the rest was distributed more or less uniformly. In 2003 Coahuila, Guanajuato and Puebla accounted for around 57% of output. Basic petrochemical's is a typical case of geographic concentration based on the availability of a natural resource and locates in Tabasco, Veracruz and Chiapas. The Chemicals industry was concentrated in Distrito Federal, Estado de Mexico and Nuevo Leon, but in 2003 these regions lost relative to other states, particularly Guanajuato and Jalisco. Hence patterns reveal still the tendency to locate mostly in one or more of the main tra-

ditional centres but also in states in the North and Bajio. The exceptions are raw materials-oriented industries.

Table 8. Location of the Top Weighted-Concentrated Industries

Industry	1988	2003
Automotive industry	Estado de Mexico (24%) Coahuila (20%) Distrito Federal (11%)	Estado de Mexico (13%) Coahuila (23%) Puebla (17%) Guanajuato (17%) Aguascalientes (6%)
Basic petrochemical	Tabasco (32%) Veracruz (42%) Chiapas (18%)	Tabasco (38%) Veracruz (29%) Chiapas (25%)
Chemicals	Distrito Federal (48%) Estado de Mexico (29%) Nuevo Leon (8%) Jalisco (7%)	Distrito Federal (32%) Estado de Mexico (26%) Nuevo Leon (7%) Jalisco (9%) Guanajuato (6%)

Source: Own calculations.

5. Geographic Concentration and Industry Characteristics

The basic story dictated by the NEG is that the interaction of scale economies and trade costs encourages the absolute geographic concentration of manufacturing production in locations with easy access to large markets. Similarly, once firms start developing vertical input-output links one should expect the level of absolute concentration to be higher in industries which are more intensive users of intermediate inputs in final production (Amiti, 1998). Hindebrandt and Wörz (2004) point out that wages is an important variable in explaining concentration by representing the cost argument. Exports and FDI are brought into the discussion as forces driving industrial agglomeration in a context of increasing globalisation (Fujita and Hu, 2001). Thus NEG predicts that industries with higher economies of scale in production, higher industrial linkages and lower trade costs are more likely to be geographically concentrated. The effect of cross-industrial differences in wages is not straightforward. Industries paying higher wages are likely to concentrate in regions where production justifies paying more. Yet low-wage industries look for cheap locations and concentrate there; the impact on concentration will thus depend on the net effect. Facing increasing trade liberalisation and economic integration industries that rely more on exports relative to domestic sales are expected to concentrate close to their relevant markets. The concentration of FDI-dependent industries might be stronger than the concentration of total investment because foreign investors seek to benefit from agglomeration economies but this may be outweighed by some congestion effects.

We include a review of economies of scale, transport costs, wages, linkages, size, exports and FDI and calculate the indicators that, according to theory, are the best proxies to represent those characteristics. Table 9 shows how each variable is defined. Data is obtained from economic censuses and the annual industrial survey for the years 1993, 1998 and 2003 [4]. We acknowledge that some are very rough proxies but data availability is an important limitation [5].

Table 9.   Definition of variables

Variable	*Proxy*	
Scale Economies (SE)	Average plant size (Ge, 2003)	SE = Total employment/number of establishments
Transport costs (TC)	Share of freight expenses in total costs	TrC = Freight expenses/Total costs
Linkages (Link)	Value of intermediate consumption (IC) within the value of total output (VTO)	Lin = IC/VTO
Wages (W)	Average wage per employee in the industry (Hindebrandt and Wörz, 2004)	W = Total wages/Total employment
Exports (Exp)	Shares of exports within total sales (Ge, 2003)	Exp = Value of exports/Total sales
Foreign Direct Investment (FDI)	Share of foreign investment within total investment (Ge, 2003)	FDI = Gross fixed capital formation of foreign origin/Total gross fixed capital formation

Source: Author.

For a first look at industry characteristics we rank industries according to the calculated value. In Table 10 the industries with the highest and lowest values for each characteristic are shown. Largely oil related activities operate under high scale economies and pay the highest wages; the cement industry bear the highest transport costs; the Machinery and equipment for offices and informatics is the main exporter and one with strong linkages whereas is also strongly based on foreign capital.

To explore the potential relationship between the distribution of industries according to concentration levels and their distribution according to their respective characteristics table 11 presents the Spearman's rank correlations between the GI of geographic concentration and the set of industry characteristics. The Spearman's rank correlation coefficient indicates that:

a)   The statistical correlation between the ranking based on absolute concentration and the ranking based on scale economies is strong and significant.

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[4] The values of export in 1993 correspond to data of the industrial survey in 1994.

[5] Imports are an essential aspect to consider in exploring the net effects of trade; yet data on imports of four-digit industries is not available in the economic census. Plant size is a straight away proxy of SE but still widely used. The linkage variable does not discriminate between the origin of the intermediate consumption (foreign, domestic, intra-industry or inter-industry).

Table 10. Low and High Intensity Industry Characteristics

	1993		1998		2003	
	L	H	L	H	L	H
SE	Tort	Oil refining	Tort	Basic petroche-mical	Tort	Basic petroche-mical
TC	Ceramics and pottery	Cement	Ceramics and pottery	Cement	Leather and fur	Cement
Exp	Dairy products	MEOI	Tort	MEOI	Sugar	MEOI
Link	Tobacco	MEOI	Tobacco	MEOI	Tobacco	Electronic equipment
W	Tort	Oil refining	Tort	Pharma-ceuticals	Ceramics and pottery	Oil refining
FDI	Oil refining	MEOI	Oil refining	Rubber manufac-turing	NA	NA

Source: Author.

Table 11. Spearman's Rank Correlations of Concentration and Industry Characteristics

		SE	*LINK*	*TC*	*W*	*EXP*	*SIZE*	*FDI*
1993	CC	0.35***	–0.10	–0.03***	0.37***	0.34*	–0.24*	0.42**
	Sig	0.012	0.468	0.009	0.009	0.019	0.090	0.002
1998	CC	0.44***	–0.06	–0.27*	0.34**	0.25***	–0.17	0.28*
	Sig	0.002	0.705	0.63	0.016	0.085	0.25	0.048
2003	CC	0.57***	0.16	–0.30**	0.42***	0.43***	–0.09	—
	Sig	0.000	0.273	0.034	0.003	0.002	0.532	—

CC: Correlation Coefficient.
Sig: Significance.
*** Correlation significant at the 0.01 level (2-tailed).
 ** Correlation significant at the 0.05 level (2-tailed).
  * Correlation significant at the 0.10 level (2-tailed).

b) There is a significant but negative correlation between the rankings of geographic concentration and transport costs.
c) The rank correlation between concentration and wages is positive and significant.
d) Overall there is no significant correlation between size and concentration rankings, or between linkages and concentration ranks. In both cases the relationship appears to be negative.

e) The rank correlation between exports and geographic concentration is positive and significant.

f) The correlation with FDI is significant but low.

This would imply that industries with large economies of scale, pay high wages, have low transport costs and are dependent on export sales and FDI will concentrate geographically. By and large this agrees with the predictions dictated by NEG. However, linkages do not seem to be positively related to the difference in concentration levels among industries.

Because rank correlations only help to gain an approximation of the relationship between variables we undertake a multivariate analysis. Reduced form specifications, which make use of a set of industry characteristics as explanatory variables, are an empirical framework common in the literature in order to explain cross-industry variation of geographic concentration. Here this approach is exploited for an analysis of Mexican industries. We examine the absolute geographic concentration of manufacturing industries using the GI as dependent variable. Even though we are limited for the lack of data in various periods we also assess if trade and investment liberalisation play a role in explaining cross-industry variations in concentration. From that we can indirectly infer whether integration with North America has promoted a different spatial landscape in the mix of individual manufacturing industries in Mexico.

We have two alternative specifications:

Equation [1]: $GI_{it} = \beta_0 + \beta_1\ Se_{it} + \beta_2\ TrC_{it} + \beta_3\ Link_{it} + \beta_4\ W_{it} + \beta_5\ Size_{it} + \beta_6\ Exp_{it} +$
$$+ \beta_7\ FDI_{it} + \varepsilon_{it}^k$$

Equation [2]: $GI_{it} = \beta_0 + \beta_1\ Se_{it} + \beta_2\ TrC_{it} + \beta_3\ Link_{it} + \beta_4\ W_{it} + \beta_5\ Size_{it} + \beta_6\ Exp_{it} + \varepsilon_{it}^k$

Equation 1 assumes that absolute concentration of industries depends on a series of characteristics enumerated by the NEG, specifically economies of scale, transport costs and linkages, while we also include wages to reflect the cost argument. Industry size is included in the regression as a variable which controls for the fact that a larger industry will find it more difficult to concentrate due to congestion effects (Alecke *et al.,* 2006). We aim to find whether the process of trade liberalisation and formal integration with North America has had an impact on the spatial landscape of industries. Exports and FDI are proxies to capture the trade liberalisation and integration effects. A component of the cross-section variation might be attributable to the geographic adjustment of industries after external trade shocks, and the export and FDI variables more directly address this issue. Due to data limitations our observations for equation 1 include only the years 1993 and 1998. This is estimated for a panel of 49 industries *i* (having eliminated those industries with missing data [6] and a couple of extreme outliers [7]).

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[6] Tortillas and Nixtamal milling, Sugar and Ceramics.
[7] Basic Petrochemical and Oil processing.

Equation 2 is estimated for 3 points in time 1994, 1998 and 2003 for which we have data of the relevant variables excepting FDI. The second specification is subject to the issue of omitted variables as we do not include this variable. As a matter of fact more omitted variables might affect concentration but we still aim to gain insights on the effect of those variables included in our model. We assess whether the following set of predictions find support in the data we have:

- Large economies of scale and linkages have a positive impact on absolute concentration of industries, whereas industries with high transport costs tend to dispersed.
- There is an effect of wages which is subject to the other locational conditions, therefore no *a priori* prediction on the direction of the effect is made.
- Industries with higher dependence on export are more concentrated in space.
- FDI dependence increases the chances of geographic concentration.

6. Estimation and Results

We estimate Equation 1 and 2 with a panel data technique using *EViews* 6 through the Swamy and Arora estimator of component variances assuming random effects for the cross section. This particular form is chosen by reason of data characteristics (2 and 3 observations) and after testing for model misspecification. We employed is the Hausman test to compare the fixed and random effects estimates of coefficients which does not lead us to reject the null hypothesis that the random effects model is not a misspecification. Panel data often involves the existence of serial correlation, contemporaneous correlation and heteroscedasticity; such violations to the fundamental assumptions of the best estimates are corrected by the PCSE (Panel Corrected Standard Error) methods since these are more precise (Beck, 2001). In order to obtain a robust estimation, we employ a Cross-section SUR-PCSE method which implies an estimate that corrects for the presence of contemporaneous correlation and allows for more general serial correlation. We are interested in the statistical significance of the regressors and the direction of their impact on absolute concentration rather than the magnitude of the effect. The results are reported in Table 12.

The estimates for equation 1 suggest that some variables, excepting industry size, scale economies and FDI, are statistically significant at conventional significant levels. Industry size is not significant but shows a coefficient such that big industries find less convenient to concentrate in space due to agglomeration diseconomies. High exports and wages spur geographic concentration which stresses the importance played by trade and salary driven concentration. Exports have a positive impact on the dependent variable indicating that the more the industry relies on exports the more concentrated it appears. Similarly, industries paying higher wages are more likely to concentrate. Statistically linkages and wages appear to be the most important determinants of spatial concentration of industries. Nevertheless linkages, together with transport costs, exercise a significantly negative effect on concentration. High-transport cost activities would tend to be more dispersed than the rest of industrial sectors

Table 12. Panel estimates for Equation 1 and 2

Variable	Equation 1	Equation 1 Restricted model	Equation 2
SE	–3.05E-05 (5.30E-05)	–2.16E-05 (6.15E-05)	8.32E-06 (0.0001)
TrC	–1.1912** (0.4996)	–1.1990*** (0.5133)	–1.3297*** (0.2746)
Wages	0.0021*** (0.0007)	0.0022*** (0.0008)	0.0016*** (0.0008)
Linkages	–0.1486*** (0.0129)	–0.1496*** (0.0158)	–0.1405*** (0.0252)
Size	–0.8035 (0.7901)	–0.7784 (0.7516)	–0.4011 (0.6659)
Exports	0.0835** (0.0409)	0.0840*** (0.0426)	0.0873*** (0.0352)
FDI	0.0208 (0.0310)	— —	— —
R^2	0.23	0.28	0.24
Num. of obs	98	98	147

*** Significant at 1% level.
 ** Significant at 5% level.
  * Significant at 10% level.
Standard errors in parenthesis.

as expected. The sign of the coefficient for linkages is rather surprising. These show a negative impact on concentration, implying that industries with high intermediate consumption are more dispersed. Even though they try to explain a different dimension of the geography of manufacturing Mendoza and Pérez (2007) find quite similar results: the relevance and the sign of transport costs, wages and linkages.

The negative coefficient of our intermediate consumption intensity variable is also compatible with the results in Vogiatzoglou (2006) who find an interpretation for this: linkages become weaker as an inward-looking economy liberalises and integrates into the international economy because for firms there is no need anymore to be located close to domestic suppliers of intermediate inputs and the local market, since inputs can be obtained from international markets (while products can be exported) resulting in de-agglomeration. Other explanation is relative to the way linkages are measured. If we not distinguish between domestic and international intermediate goods, an industry may exhibit a high degree of intermediate goods-intensity and at the same time be dispersed, if intermediate inputs are obtained from abroad which is highly likely in the NAFTA context. Our proxy neither differentiate own industry linkages (self-reinforcing concentration) from inter-industry linkages (agglomeration). We cannot see whether the negative effect is due to some congestion cost effect caused by the agglomeration of overall activity or to competition for input access between firms in the same industry. Moreover this proxy accounts

only for cost linkages, while demand linkages (sales to consumers) are not incorporated.

Our results are also incompatible with predictions in the cases of scale economies and FDI. One important reason could be the way we measure those variables. However the estimates for scale economies are compatible with some findings in the literature. Mendoza and Pérez (2007) do not find evidence showing that scale economies are a factor triggering concentration of manufacturing, besides they obtained a negative sign possibly justified by urban congestion. In Vogiatzoglou (2006) economies of scale affect negatively concentration.

When both exports and FDI are included in the regression the coefficient on FDI is positive but statistically no significant. This might be because there is an important correlation between exports and FDI as industries with a high share of foreign investment are also export oriented (FDI is an important engine of export capacity in Mexico). The correlation coefficient between these two variables is about 0.45 which is important but not extremely high. FDI is particularly industry-selective. By looking at industries which are the two major receivers of FDI in Mexico (electronics and automotive) the later is not among the most concentrated industries. This is a plausible explanation if we do not consider cases such as Pharmaceuticals a concentrated industry and also a significant receiver of FDI. The fact that the car industry or other industries dependent on FDI do not appear to be concentrated is attributable perhaps to the index employed and also to the level of industrial aggregation. But the export variable is subject to some of these problems and so the evidence on FDI is inconclusive. In any case we perform the redundant variables test to see if in a restricted model, one excluding FDI, this variable is redundant. The F-statistics value does not lead us to reject FDI as a redundant regressor in the model.

We estimate eq. 1 for the restricted model (excluding FDI) and the results are not modified considerably only exports increase its statistical significance. To check the robustness of results we estimate eq. 2 that includes 2003. This allows us to contrast the restricted model considering different periods, a panel for 1993 and 1998 and the panel with three years. Comparing with previous results there is no considerable change in the sign and significance of the estimated coefficients with the exception of the sign of scale economies which in any case remains no significant.

Overall the results support one of our key hypotheses: industries with high dependence on exports tend to concentrate (in regions with easy access to relevant markets). Yet the relationship between industry characteristics, exports in particular, and average concentration is not straightforward. According to what was observed after the formalisation of NAFTA a process of average dispersion of industries continued taking place. If all industries were equally dependent on exports thus increasing exports resulting from liberalisation and integration had fostered growing average concentration of industries which did not happened. This confirms the selective effect of liberalisation and NAFTA and the across industry differences of the impact on the geography of aggregate manufacturing. Besides, a number of additional factors, other than globalisation drive the progression of average geographic concentration.

7.   Conclusions

In this paper the geography of individual manufacturing industries has been assessed. The findings refer to a number of empirical patterns of the geographic distribution of manufacturing industries across Mexican states. Manufacturing industries in Mexico have become, on average, more dispersed in terms of both production and employment. When looking at the weighted average concentration this result is supported and that dispersion is the tendency over the long-run. The average dispersion of individual industries that the data in this paper coincides with the process of dispersion of the whole of manufacturing that has been found in previous research. For the most part, only a third of all industries increased their concentration. The most concentrated industries being Pharmaceuticals and Machinery and equipment for offices and informatics, whereas the most dispersed were Tortillas and Beverages. The most concentrated industries typically follow the location pattern found in the whole of manufacturing sector. Pharmaceuticals, machinery and equipment for offices and informatics, and publishing and printing locate in Estado de Mexico, Distrito Federal, Jalisco and Nuevo Leon; this seems to have been the predominant and reinforcing pattern while industries like Footwear are clustering more in Guanajuato. Similarly, concentrating and larger industries tend to locate in traditional industrial regions, the north but increasingly more in the Bajío.

Thus no matter whether we refer to one or other index (Gini or Herfindahl), weighted or un-weighted average concentration or if we refer to employment or output, average dispersion of manufacturing has taken place. Since the trend dates back since at least the late 1980s one can not state that those tendencies have their origin on the NAFTA signing. Yet some adjustment can be attributed to the shift in the trade and industrial schemes that brought increasing liberalisation of trade and investment, and to the deepening of economic integration with North America. The analysis seems to suggest that the new trade practices did not enhanced average geographic concentration of manufacturing industries but stimulated concentration of export oriented activities.

The second part of the paper included an assessment of the relationship between industry characteristics and concentration of industries. Overall wages and exports play a role in explaining concentration whereas linkages and transport cost explain dispersion. Some of the characteristics enumerated by the NEG found limited support in the data set considered: FDI and economies of scale are not related to concentration of industries. The size of industries appears to be unimportant in explaining the concentration of individual sectors. Importantly for the central question of this paper is that exports, as a measure of increasing trade liberalisation, are highly significant to explain the cross-industry variations in geographic concentration having a positive impact on concentration levels. Yet the role of FDI as a driver of concentration of an industry is contentious on the light of our findings.

Results are relevant as the opening up of the Mexican economy signified increasing pressures for the federal government for privileging or prioritising those

regions and industrial activities with more potential for competing internationally in detriment of those which have not had favourable conditions in this respect. Exports are a driving force of concentration but the tendency towards concentrating although generates some gains economic in nature they are unequally distributed and can have collateral effects. The heterogeneous regional structure and the differentiated progress of industries in terms of location and concentration have repercussions on other facets such as the cultural, social and political life.

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