Is Mexico a Lumpy Country?*

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Abstract: Courant and Deardorff (1992) show theoretically that an extremely uneven distribution of factors within a country can induce behavior at odds with overall comparative advantage. We demonstrate the importance of this insight for developing countries. We show that Mexican regions exhibit substantial variation in skill abundance, offer significantly different relative factor rewards, and produce disjoint sets of industries. This heterogeneity helps to both undermine Mexico's aggregate labor abundance and motivate behavior that is more consistent with relative skill abundance.

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Developing countries have experienced a dramatic shift in trade policy over the last 20 years, often with unexpected results. As one of the earlier liberalizers, Mexico has received a great deal of attention as a country that did not seem to follow the patterns suggested by trade theory. After joining the GATT in 1986, wage inequality increased in Mexico, inspiring research supporting a wide array of explanations (Cragg and Epelbaum 1996, Revenga 1997, Feenstra and Hanson 1997, Meza 1999, Feliciano 2000, Robertson 2000, Esquivel and Rodriguez-Lopez 2003, Verhoogen 2008).

While most of these papers look at the years following the entrance into the GATT for an explanation, Hanson and Harrison (1999) suggested that Mexican tariffs prior to liberalization were relatively high for labor-intensive goods and that, after liberalization, the country disproportionately reduced tariffs on labor-intensive products. This pattern of protection was puzzling: why would a labor-abundant country like Mexico have protected its abundant rather than its scarce factor? Mexico exhibited other puzzling features as well. This relatively labor-abundant country is also an exporter of relatively skill-intensive goods. Before 1986, the year Mexico joined the GATT, more than half of the country's exports were in Chemicals and Machinery, which use skilled workers relatively intensively compared with other Mexican sectors (Figure 1). Table 1 reveals that these industries have the third and fourth highest average education levels and the second and fourth highest non-production to production worker ratios in Mexico. Exports of textiles, which are relatively less-skill-intensive, in contrast, were low. As a result, Mexico's trade pattern, like its tariff structure, was more consistent with that of a relatively skill-abundant country than a skill-scarce country.

In this paper, we argue that Mexico's counter-intuitive behavior is driven in part by its internal distribution of factors. Courant and Deardorff (1992) show theoretically that extreme factor "lumpiness" across regions within a country can prompt production and trade patterns that contradict the country's overall comparative advantage. To our knowledge, their contribution has not yet found any empirical support. Our focus on Mexico's factor lumpiness here, therefore, serves both to highlight the empirical relevance of Courant and Deardorff's result and to help resolve a well-cited puzzle about the effect of trade liberalization in Latin America.

Regional differences within Mexico are stable and significant, leading some to focus on geographic aspects of globalization. Chiquiar (2008), building on Hanson (1997), argues that some regions are more exposed to globalization than others, leading to the emergence of Stolper-Samuelson effects in globalized regions but different effects in other regions. These results raise the possibility that, in the language of trade theory, Mexico may be divided up into different diversification cones, where the word "cone" refers to the set of region endowment vectors that select the subset of industries in which regions specialize. In Mexico's case, sufficient regional concentration of skilled workers forces skill-abundant regions within the country to offer relatively low skilled wages and thereby specialize in the production of relatively skill-intensive goods. As a result, the country becomes a net importer of labor-intensive products and has an incentive to protect its abundant rather than scarce factor.

We examine the plausibility of factor lumpiness as an explanation for Mexico's behavior by testing two of its key implications, namely whether relative factor prices are equal across the country's regions and whether regions within Mexico produce the same bundle of industries. We use a technique developed by Bernard et al. (2005) that is based on very general assumptions about production, markets and unobserved differences in region-industry factor quality. We find that the relative skilled wage varies significantly and substantially across Mexican regions and that this variation is associated with product-mix specialization. As implied by theory, regional skill abundance and the relative skilled wage are negatively correlated.

Our analysis demonstrates that Courant and Deardorff's insight is particularly important for understanding the impact of trade liberalization on developing countries. In a skill-abundant country like the United States, skilled-worker lumpiness merely reinforces aggregate comparative advantage by promoting relatively higher exports of skill-intensive goods.[1] In labor-abundant countries like Mexico, however, extreme regional concentration of skilled workers can result in trade patterns and import protection that contradict the implications of the standard model.

Our findings further highlight the usefulness of factor lumpiness as an explanation for why Latin America presents such a persistent "challenge to conventional wisdom" (Wood 1997). They also emphasize the need for further empirical and theoretical research into its consequences. Table 2, for example, reveals that Latin American countries generally, and Mexico in particular, have exceptionally high rates of urbanization among developing countries. If skilled workers tend to cluster in cities to a greater extent in Latin America than in other parts of the developing world, then Latin American economies may be more susceptible to rising income inequality (i.e. rising skill premiums) as they liberalize. More generally, reducing trade barriers in Latin America

[1] Bernard et al. (2005) report a lack of relative factor price equality across regions of the United States. Debaere (2004), discussed further below, investigates factor lumpiness in Japan, India and the United Kingdom.

may have very different consequences than similar reforms in Asia or Africa, where skilled workers are distributed more evenly.

This paper makes two additional contributions to the study of globalization. First, our findings regarding intra-national factor price equality complement a broader inquiry into the extent to which relative factor prices are equal across countries. Indeed, given that regions within a country may more closely approximate an integrated equilibrium than countries within the world trading system, factor price inequality within a country casts further doubt upon the existence of factor price equality internationally.[2]

Our analysis also reveals that gauging the degree of regional specialization *within* countries is useful for understanding the within-country effects of trade liberalization *across* countries. By expanding the set of goods countries produce, factor lumpiness extends the product-mix overlap of countries with very different relative factor endowments. This expansion elevates the level of direct competition between countries with markedly different relative wages, thereby rendering them susceptible to relative wage movements via price-wage arbitrage that would not occur under a more even internal distribution of factors.

The remainder of the paper unfolds in six sections. First, we briefly review the findings of Courant and Deardorff (1992) to illustrate how factor lumpiness influences production and trade patterns. Since we do not extend the theory, we present only a brief graphical description to illustrate the basic concepts. In Section II we describe the data and stylized facts that emerge from them. Section III outlines our test for factor price

[2] Recent research by Repetto and Ventura (1997), Debaere and Demiroglu (1998), Davis and Weinstein (2001) and Schott (2003) indicates that countries span multiple cones of diversification.

equality. Empirical results are presented in Sections IV and Section V discusses the potential influence of maquiladora production on our results. Section VI concludes.

I. Trade and Lumpiness

To illustrate the insights of Courant and Deardorff (1992), consider a world with two goods (X and Y) that are produced with two factors (N and P for skilled non-production workers and unskilled production workers, respectively) in a country with two regions (A and B). Further assume that the country is small and open in the sense that it takes relative goods price as given, and that factors do not move between regions within a country.[3] The consumption vector is therefore fixed, as relative consumption depends only on relative prices. Assume good X is skill (N) intensive and good Y is labor (P) intensive.

The basic intuition is straightforward. We begin by assuming that the two factors are evenly distributed between the two regions and that the regions are of (approximately) equal size. Given a usual production technology, the initial relative endowment of factors within the country can be represented by the familiar Edgeworth box shown in Figure 2 as point 1. The points along the upward sloping diagonal OAOB are the points that represent an equal relative distribution of factors in the two regions A and B. Endowments falling into the area of the parallelogram OAaOBb represent endowments that would elicit production of both goods by both regions as well as factor price equality (FPE) within the country. Along the diagonal OAOB both regions would produce identical relative amounts of the two goods. Endowments within the

[3] We address the empirical validity of this assumption later in the text.

parallelogram above (below) the diagonal result in region A producing relatively more of good X (Y).

If factor N were reallocated from B to A, such as along the arrow from point 1 to point 2, production of X would increase in A and fall in B until the border of the parallelogram was reached. This would have no effect on international trade, however: given fixed relative demand, the increased production of X in A is offset by a decrease in the production of X in B.

At the border of the parallelogram, however, region B would stop producing X altogether and completely specialize in the production of Y. Moving further along the arrow to point 2 (outside the parallelogram) increases the production of X by A without a corresponding decrease in the production of X by B. Since world prices are fixed by assumption, the excess production of X is exported. In fact, any endowment point in the areas labeled "Export X" represents an allocation of factors that is sufficiently lumpy to induce exporting of X.

Regional endowments within the parallelogram result in relative factor price equality across regions. As a result, factor allocations from point 1 to the border of the parallelogram have no effect on relative wages. Once the endowment point crosses the border, however, regional relative wages and product mix diverge. It is precisely this implication of the model – a breakdown of relative factor price equality and concomitant differences in regional product mix – that we test for in the Mexican data.[4]

[4] Deardorff (1994) offers an alternate approach for verifying factor lumpiness that indirectly tests for the conditions that give rise to factor price equality, i.e. whether the factor abundance of regions is bounded by the factor intensity of industries as illustrated in Figure 2. The reliability of that approach, however, depends upon the relative aggregation of industries and regions (see Debaere 2004). The empirical technique used in this paper is robust to these problems (see Bernard et al. 2004).

The relationship between factor lumpiness and the pattern of trade protection is straightforward. Without geographically concentrated factors, the relative wage of skilled workers in Mexico would fall with trade costs as Mexico takes advantage of its overall comparative advantage in labor-intensive goods. With skilled-worker lumpiness, however, the relative wage of skilled workers rises because opening to trade increases exports of the skill-intensive good, raising its price and the relative wage of skilled workers along with it. Since there is no mechanism for unbalanced trade, increased exports of the skill-intensive good mandate greater imports of the less-skill-intensive good, providing an incentive for protection of the abundant factor.

A many-good, multiple-cone equilibrium extension of the model is useful for illustrating how factor lumpiness in Mexico can increase the range of goods Mexico produces in common with even more labor-abundant countries, like China. This extension is represented with a Lerner diagram in Figure 3. The figure displays two Mexican regions, M_A and M_B, which have equal numbers of unskilled workers but an unequal allocation of skilled workers. These regions inhabit cones of diversification defined by four goods, denoted by Leontief unit value isoquants, that increase in skill intensity from 1 to 4.[5] The skill intensities of each good are noted by dashed lines emanating from the origin. Figure 3 also notes Mexico's aggregate endowment point.

Without lumpiness Mexico occupies the middle cone of diversification. In this position, it would be a producer of goods 2 and 3 and offer workers the same relative wage, w_A^N / w_A^P, in each region. Assuming it was sufficiently labor abundant within the middle cone of diversification, it would be also be an exporter of relatively labor-

[5] We use Leontief production technologies in Figure 3 to keep the diagram simple. The same story can be told using technologies that allow for factor substitution.

intensive good 2 and an importer of goods 4, 3 and 1. As a result, protection of the skill-intensive import sector would be most likely. As a resident of the middle cone, Mexico as a whole would produce one good that overlaps with the most skill-abundant cone and one good that overlaps with the most skill-scarce cone. Occupants of these cones might include United States and China, respectively.

Factor lumpiness within Mexico forces M_B into a more labor-intensive cone of diversification than region M_A via the same logic outlined above. As a result, M_B produces goods 1 and 2 rather than 2 and 3 and offers a relatively high skilled wage compared to region M_A, i.e. $w_A^N / w_A^P < w_B^N / w_B^P$. The geographic concentration of skilled workers induces the country into being an exporter of the relatively skill-intensive good (3) and an importer of its relatively labor-intensive good (2), thus changing the country's incentives for protection. Indeed, the potential demand for import protection is heightened by the fact that M_B now produces a product-mix (goods 1 and 2) that is identical to the product mix of the world's most labor-abundant countries. As a result, relative wages in Mexico are susceptible to product price movements in good 1 as well as goods 2 and 3. Declines in the relative price of good 1, due to China's emergence as a major exporter, for example, lower the relative wage of low-skilled workers in region M_B and heighten the country's overall income inequality more so than would occur if the country's factors were evenly distributed.

Factor lumpiness provides an explicit rationale for otherwise problematic explanations of Mexico's tariff and trade patters. It may seem intuitively appealing to suggest that Mexico had an incentive to protect and be a net importer of labor-intensive goods in the absence of factor lumpiness if it were primarily concerned about trade with relatively labor-abundant trading partners. Both Hanson and Harrison (1999) and Robertson (2004), for example, speculate that the threat of competition from countries more labor-abundant than Mexico may have been a factor in the country's decision to protect labor-intensive industries relatively heavily both before and after joining the GATT in 1986.[6]

Two facts, however, are at odds with this explanation. First, data from the NBER trade database show that, from 1970 to 1992, Mexico's annual average trade share with countries that were clearly relatively skill abundant was greater than 90 percent throughout the period (i.e. both before and after relatively high distortions on labor-intensive goods were reduced), including the United States and Canada (69 percent), Europe[7] (16 percent), and Japan, Australia, and New Zealand (5 percent). Second, Mexico's dominant import substitution industrialization paradigm, which shaped tariffs and is often said to have formally ended when Mexico joined the GATT, was motivated by concerns about the adverse effects of trade with more-developed, not less-developed, countries.

These facts suggest that concern about trade with more labor-abundant countries – in the absence of factor lumpiness – is not a compelling explanation of Mexico's behavior. Factor lumpiness implies an increase in the set of industries Mexico and the world's most labor-abundant countries produce in common. As a result, Mexican relative

[6] Hanson and Harrison (1999) present evidence showing that, prior to GATT, Mexican tariffs were higher on less-skill-intensive industries. This pattern remains after GATT as well. A bivariate, industry-level regression of average MFN tariff rates (percent) on industry skill intensity (i.e., the ratio of non-production to production workers), weighted by industry employment, yields coefficients (and standard errors) of -17.6 (4.7) and -7.1 (2.5) for 1985 and 1987, respectively. The relatively large tariff reductions on less-skill-intensive goods that contributed to the change in prices documented in Robertson (2004) were not enough to change the protection bias towards less-skill-intensive industries.

[7] Europe includes Belgium-Luxembourg., Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, United Kingdom, EEC n.e.s, Austria, Finland, Iceland, Norway, Sweden and Switzerland.

wages are influenced by a greater number of goods via price-wage arbitrage than would be the case if all regions of the country inhabited the same cone of diversification.

II. Data and Stylized Facts

The ideal data for analyzing lumpiness in Mexico would include comprehensive information (over both regions and industries) on employment and wages over a relatively long time period. Mexico's Industrial Census, conducted by the *Institutio Nactional de Estadística Geografia e Informatica (INEGI),* Mexico's national statistical agency, is well suited for this exercise. For this study, we use manufacturing data from the 1986, 1989, 1995, and 1999[8] Industrial Censuses, which provide data for the prior year. The Census contains information on the employment of production workers (*obreros*) and non-production workers (*empleados*), as well as aggregate payments to each type of worker (the wagebills).[9] The data classify Mexican industries using the C*lasificación Mexicana de Actividades y Productos (CMAP)* which, over all years, contains 314 six-digit industrial categories (the industries listed in Table 1 represent the first two digits of the six-digit classification system).

The data cover 32 Mexican regions: 31 states and the Federal District (i.e., Mexico City). Figure 4 shows the Mexican states, and Table 3a shows the distribution of total manufacturing employment across states. In 1985, the central region of Mexico (Mexico City and Mexico State) had 35% of all manufacturing employment. This share falls over time, which Hanson (1997) notes and attributes to trade liberalization that shifts

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[8] More information about the Mexican Industrial Census can be found at http://www.inegi.gob.mx.

[9] Use non-production worker status as a proxy for skilled workers seems to capture much of the skill segregation between industries in Mexico. Robertson (2004) shows that Mexican production workers have less education in every industry than non-production workers, and that industries with a higher ratio of non-production workers also have higher average education levels.

the focus of the market towards the border. (We discuss this shift in more detail in Section V.)

Table 3b reports the number of industries produced in each region. The number of industries is highest in Mexico State and Mexico City and lowest in Baja California Sur, Campeche, Queretaro and Quintana Roo. A key implication of factor lumpiness is that regions in different cones produce different sets of goods. Below, we test whether product mix overlap across regions is a function of estimated relative factor rewards.

III. Production Structure and Relative Wages

We test for the equality of relative wages across Mexican states using an empirical approach developed by Bernard et al. (2005). This test is robust to differences in unobserved factor quality as well as variation in the composition of factors both across regions and industries. We briefly review the derivation of the approach here.

We begin by assuming that production in industry *j* and region *r* can be represented with a constant returns to scale technology that combines quality-adjusted skilled workers *(N)* , unskilled workers *(P)* , and capital *(K)*. Using *B* to denote the unit cost function, θ_{rj}^{z} to denote the unobserved quality of factor *z*, and w_{r}^{z} to represent the wage of the quality-adjusted factor *z*, cost minimization generates the following relative demand for observed labor:

$$\frac{\tilde{N}_{rj}}{\tilde{P}_{rj}} = \frac{\theta_{rj}^{P}}{\theta_{rj}^{N}} \frac{\partial B_{rj} / \partial w_{r}^{N}}{\partial B_{rj} / \partial w_{r}^{P}} . \tag{1}$$

The null hypothesis is that quality-adjusted relative wages are the same across all regions within each industry. Under the null, observed wages differ across regions within an industry only because of unobserved differences in factor quality. Using region *s* as a benchmark and a tilde (~) to denote observed values, observed relative wages can be represented as

$$\frac{\tilde{w}_r^N}{\tilde{w}_r^P} = \frac{\theta_{rj}^P}{\theta_{rj}^N} \frac{\tilde{w}_s^N}{\tilde{w}_s^P} . \tag{2}$$

If we then multiply observed relative wages and employments in (1) and (2), the unobserved factor quality terms cancel out. If quality-adjusted relative wages are equalized across regions and relative unit factor input requirements are the same, then observed relative wage bills $\tilde{W}$ would equalize across regions:

$$\frac{\tilde{W}_{rj}^N}{\tilde{W}_{rj}^P} = \frac{\tilde{W}_{sj}^N}{\tilde{W}_{sj}^P} . \tag{3}$$

The alternative hypothesis is that quality-adjusted relative wages differ across regions *r* and *s* by a factor γ_{rs}. The source of the regional variation in quality-adjusted relative wages is taken to be exogenous and can include variation in factor endowments, trade costs, or non-tradable amenities. A key implication is that relative unit inputs would also vary within an industry, which, in turn, implies that observed relative wage bills differ across regions. The difference in wage bills would be a function of γ_{rs}, which we represent as $\eta_{rsj}(\gamma_{rs})$. Under the alternative hypothesis,

$$\frac{\tilde{W}_{rj}^N}{\tilde{W}_{rj}^P} = \eta_{rsj} \frac{\tilde{W}_{sj}^N}{\tilde{W}_{sj}^P} , \tag{4}$$

so that a finding that $\eta_{rsj} \neq 1$ is sufficient to reject the null hypothesis. To test this hypothesis empirically, we normalize the relative wage bill in each region *r* by the relative wage bill in some region *s*. Taking logs, we then obtain the following empirical specification:

$$\ln\left(\frac{RW_{rj}}{RW_{sj}}\right) = \sum_r \alpha_r^s d_r + \varepsilon_{rsj} \qquad (5)$$

in which $RW=W^N/W^P$, d_r is a set of regional dummy variables, and ε_{rsj} is a stochastic error term. Finding that the set of regional dummy variables is jointly significant is the empirical analog to finding that $\eta_{rsj} \neq 1$ and therefore is sufficient to reject the null hypothesis. Furthermore, as described by Bernard et al. (2005), positive estimated values of α_r^s imply lower relative wages for skilled workers in region *r* relative to the base region.

IV. Empirical Results

A. Baseline Estimates

We begin by estimating (5) using all of Mexico as the base region. The base region relative wage is calculated by summing the wage bill for each of the two types of workers across all regions by industry, and then dividing these sums. The relative wage for each industry-region is calculated by summing all of the payments to each type of worker within each industry-region and taking the ratio of the sums. The dependent variable in (5) is the latter divided by the former.

Table 4 contains the initial results for each census year. Several results are noteworthy. First, nearly all of the estimated coefficients on the regional dummy variables are statistically significant. They are also jointly significant, which is sufficient to reject the null hypothesis of factor price equalization across Mexican states. Second, the vast majority of coefficients are negative. In fact, there are only two statistically significant positive coefficients: Mexico City and Mexico State. These two regions have the largest shares of manufacturing employment as well as the largest shares of skilled workers.

Table 4 also shows the results to be relatively stable across time periods. In all years, Mexico and Mexico City are the only regions with positive and statistically significant coefficients. As well, the vast majority of the coefficients that are negative and significant in 1985 are also negative and significant in 1999. The similarity of coefficients across time in Table 4 also reveals that relative wage differences are relatively stable. The estimated coefficients for Mexico State, for example, are the same in 1986 and 1999. For Mexico City, the coefficients for 1986 and 1999 are 0.218 and 0.233. Assuming a CES production function and an elasticity of substitution of 2.0, these two estimates would correspond to relatively skill-abundant Mexico City having quality-adjusted relative wages for skilled workers (compared to unskilled workers) that were 24% and 26% lower than the average for Mexico in 1986 and 1999. Comparing the states of Mexico and Puebla, the results suggest that quality-adjusted relative wages for skilled workers in relatively skill-scarce Puebla were 52% higher than those in the state of Mexico.

One potential concern with the results in Table 4 is that they might be overly dependent on the presence of Mexico City and Mexico State. We therefore drop Mexico City and Mexico State from the data and repeat the analysis. Table 5 contains the results. As indicated in the table, overall results without these two regions are very similar to those reported in Table 4. The relatively poor states (Oaxaca, Michoacan, Guerrero) remain near the bottom, and Nuevo Leon emerges at the top. The results in Table 5 are also stable across time. The Pearson correlation coefficient between 1985 and 1999 is 0.908 and all pairwise Pearson coefficients (matching all possible year combinations) are above 0.90. Mexico City and Mexico State certainly do stand out as positive outliers, but the same states emerge near the bottom with large, negative, and significant coefficients regardless of whether or not Mexico City and Mexico State are included.

The relative stability of the estimates raises the question of labor mobility within Mexico: why is it that persistent regional relative wage differentials are not arbitraged away by the movement of labor across regions? Hanson (2004), using Mexican Population Census data, finds within-country migration to be relatively small; workers within Mexico do not seem to move enough to erase large regional wage differentials. Topel (1986) suggests that less-skilled workers are less mobile than more skilled workers, which may apply to Mexico. If migration costs (including information) are higher than the expected gains, workers will not migrate to erase regional wage differentials.

B. Relative Wages and the Production Structure

The results in Table 4 suggest that relative wages are not equalized across regions within Mexico. Theory predicts that regional variation in relative wages coincides with differences in regional production patterns. We test for such differences formally via the OLS regression

$$Z_{rs} = \beta_0 + \beta_1 \left|\hat{\alpha}_r^s\right| + \beta_2 I_r + \beta_3 I_s + \upsilon_{rs}, \tag{6}$$

where Z_{rs} represents a the number of industries common to regions r and s, the $\hat{\alpha}_r^s$ are the estimated bilateral relative wage bill differences from equation (5), and the final term represents a stochastic error. The intuition behind this regression is that regions that have larger differences in estimated relative wages should have fewer industries in common. I_r and I_s represent the number of industries produced by regions *r* and *s*, respectively, and are included to capture the possibility that simply having more industries makes industry overlap between other regions more likely.

The results are shown in Table 6. In all census years, the number of industries in common falls as the absolute difference in the relative wage bill rises. This evidence offers strong and consistent support for the idea that the differences in regional relative wages affect the distribution of regional production. Based on the results in Table 4 for 1999, the estimated relative wage differences between Mexico City and Guerrero accounted for 23 fewer industries in common.

The results of this section are sufficient to reject relative factor price equality across Mexican states. Together with our estimates of product mix differences across states, these results lend support for the view that Mexico's distribution of factors is lumpy enough to influence the country's pattern of trade and, therefore, its pattern of trade protection.

V. The Role of Foreign Investment

An important trend in Mexican manufacturing over the past 25 years has been the development of *maquiladora* establishments. Maquiladoras are "in-bond" assembly plants that import parts into Mexico, assemble them, and then export the assembled products.[10] In this section we show that maquiladoras are concentrated in relatively skill-scarce industries in relatively skill-scarce regions. As a result, it does not appear as if

[10] For a good introduction to the maquiladora industry, see Vargas (1999).

their rise over time explains Mexico's status as a net exporter of relatively skill-intensive goods.

Maquiladoras are primarily foreign owned and, by law, had to locate in the U.S. border region prior to the North American Free Trade Agreement (NAFTA). This was to the advantage of the firms, since this location minimized transportation costs of imported inputs. It also worked to the advantage of the Mexican government because the government considered the maquiladora program part of its border development program.[11] In any case, since they exist for assembly, it is perhaps not surprising that they would locate in regions that historically have had a higher proportion of less-skilled workers. Figure 5 reports the concentration of maquiladora employment by state in 2000, while Figure 6 illustrates the rise in maquiladora establishments and employment from 1978 to 2003.

Feenstra and Hanson (1997) have shown that maquiladoras raise the relative demand for skilled workers. We, too, find that controlling for industry, maquiladoras do employ a higher ratio of non-production workers than other manufacturing plants.[12] Official statistics, however, reveal that maquiladoras are concentrated in relatively low-skill industries as measured by production worker intensity. This concentration is evident in Table 7, which compares the industrial census data described above with official maquiladora statistics.[13] Two trends are noteworthy. First, the tendency of maquiladoras to produce in low-skill industries is manifest in the non-production worker to production

[11] In fact, the maquiladora program was established in response to the end of the Bracero Program in 1965 when Mexico needed an employment strategy for migrant workers returning from the United States.
[12] Using data from Mexico's ENESTYC, we estimate a plant-level regression from the 1992 survey of the non-production/production worker ratio on a maquila dummy variable, the amount spent on machinery and equipment, two-digit industry dummy variables, and a constant (N=4855). The maquiladora variable has a coefficient (standard error) of 0.485 (0.146). See Alvarez and Robertson (2004) for a more detailed description of these data.
[13] Maquiladora data are available from INEGI at http://dgcnesyp.inegi.gob.mx .

worker employment ratio being lower in maquiladoras than in overall manufacturing in all regions. Taking into account each state's share of maquiladora employment in total manufacturing employment (in the first column of Table 7) indicates that this disparity can be quite strong. The Census versus Maquiladora N/P ratios for Baja California Norte in 1998, for example, are 0.153 and 0.078, respectively, even though 87 percent of the state's manufacturing workers are employed by maquiladoras. Second, the table indicates that Southern states generally have very little, if any, maquiladora employment.

We also find that the large increase in maquiladoras does not explain Mexico's relatively large exports of skill-intensive goods. First, the results just reported indicate that though maquiladoras are more non-production worker intensive when controlling for industry, they inhabit generally less-skill-intensive industries. Second, Mexico's data collection practices allow for a comparison of maquiladora versus non-maquiladora exports. The discrete break 1991 in the export trends reported in Figure 1 occurs because prior to that year, maquiladora exports were not counted as exports. As is evident from the figure, their inclusion does result in a slight drop (increase) in the share Chemicals (Machinery) exports, but the overall pattern of exporting remains the same.

Finally, we note that maquiladoras may actually contribute to Mexico's lumpiness by attracting less-skilled workers to the border. Table 3a, for example, shows Mexico City's falling share of manufacturing employment and the border's rising share of employment.

VI. Adjusting for Factor Quality

One potential explanation for the persistent differences across regions is that worker quality (e.g. demographic characteristics) varies systematically between regions.

To address this possibility, we apply Mincerian wage equations to labor market data used by Chiquiar (2008). The goal is to calculate relative wages after adjusting for worker quality, and calculate the quality-adjusted relative wage and relative employment in each region. We begin by estimating

$$\ln w_i = \alpha + \beta_1 education + \beta_2 sex + \beta_3 age + \varepsilon_i \tag{7}$$

separately for each state, each industry, and each occupation (production worker or nonproduction worker). The constant term α represents the wage after the effects of the human capital variables have been removed. We then generate a predicted wage for each worker using (7). To calculate the relative wage for each occupation net of individual-specific effects, we calculate the ratio

$$\frac{\alpha_{ij}^{n}}{\alpha_{ij}^{p}}, \tag{8}$$

which is the ratio of the constant term for nonproduction workers (n) and production workers (p) for each state i and each industry j. Although (7) is estimated in logs (using log wages), we use the exponential value of the constants when computing (8).

To calculate the quantity of quality-adjusted workers, we calculate the ratio

$$\left(\frac{\hat{w}}{\alpha}\right)_{hij} \tag{9}$$

for each occupation h , state i and industry j . This weights each person by their relative workforce quality. We then take the sum of (9) over all states and industries, and take the resulting number for nonproduction workers and divide it by the resulting number for nonproduction workers. This gives us the quality-adjusted quantity ratio in each state-industry.

To adjust for worker quality exercise, we use micro samples from the 2000 Mexican population census. There are advantages and disadvantages from using these data. One advantage is that the alternative, the household surveys, cover cities, rather than states, and do not cover the entire country. The advantage is that it starts with an approximately 10% sample of the nation (10,099,182 observations). From this universe, we keep all workers between 16 and 65 (exclusive) and all workers who work for pay and are not self-employed.

The next step is to identify nonproduction and production workers. We drop several occupations, such as clowns, athletes, musicians, and several service professions and divide the remaining workers into either production or nonproduction worker categories using the Mexican occupation classification. All industries are included, but the non-manufacturing industries are aggregated to the 2-digit level. The manufacturing industries are left at the finest level of disaggregation possible, which leaves us with a total of 42 industries (including manufacturing and others).

To estimate (7), we use the log of monthly labor income, which does not include income from assets. The main result is that the wage ratios and quantity ratios have an inverse relationship. The relative wage of quality-adjusted nonproduction workers is lower when the relative quality-adjusted quantity of nonproduction workers is higher. These results are consistent with our earlier findings, suggesting that our results are not being driven by systematic differences in worker quality.

VII. Conclusions

Prior to trade liberalization, skill-scarce Mexico protected less-skill-intensive industries and exported skill-intensive goods. One explanation for this puzzling behavior is Courant and Deardorff's (1992) theoretical insight that geographic concentration of factors within a country can influence countries' patterns of trade and production. A key consequence of factor lumpiness is significant variation in regional relative wages. In this paper we examine whether Mexico is a "lumpy" country by testing for intra-national relative factor price equality. We find that the relative skilled wage varies significantly across Mexican regions. We demonstrate that this variation is negatively correlated with regional skill abundance and positively associated with regional product-mix specialization, as implied by theory. Our analysis implies that Mexico's overall labor abundance may be undermined by regional heterogeneity.

Our findings suggest several extensions. First, with respect to the debate about trade liberalization and wage inequality in developing countries, it would be useful to measure the extent to which factor lumpiness contributes toward rising inequality in a broader set of countries. Mexico's internal distribution of factors, for example, may be different from those of other countries which experienced declining wage inequality following trade liberalization (Wood 1997, Inter-American Development Bank 2002). It would also be worthwhile to investigate whether Mexico's exports are more skill-intensive than those from similarly endowed but less lumpy countries.

Another fruitful extension of our analysis would be an examination of the determinants of factor lumpiness, such as urban agglomeration. While we find in this paper that Mexico is sufficiently lumpy to affect its trade and protection patterns, we do not formally inquire into the extent to which this is due to the lure of cities versus the influence of Mexico's unique northern border with the United States, where low-skill workers have concentrated.

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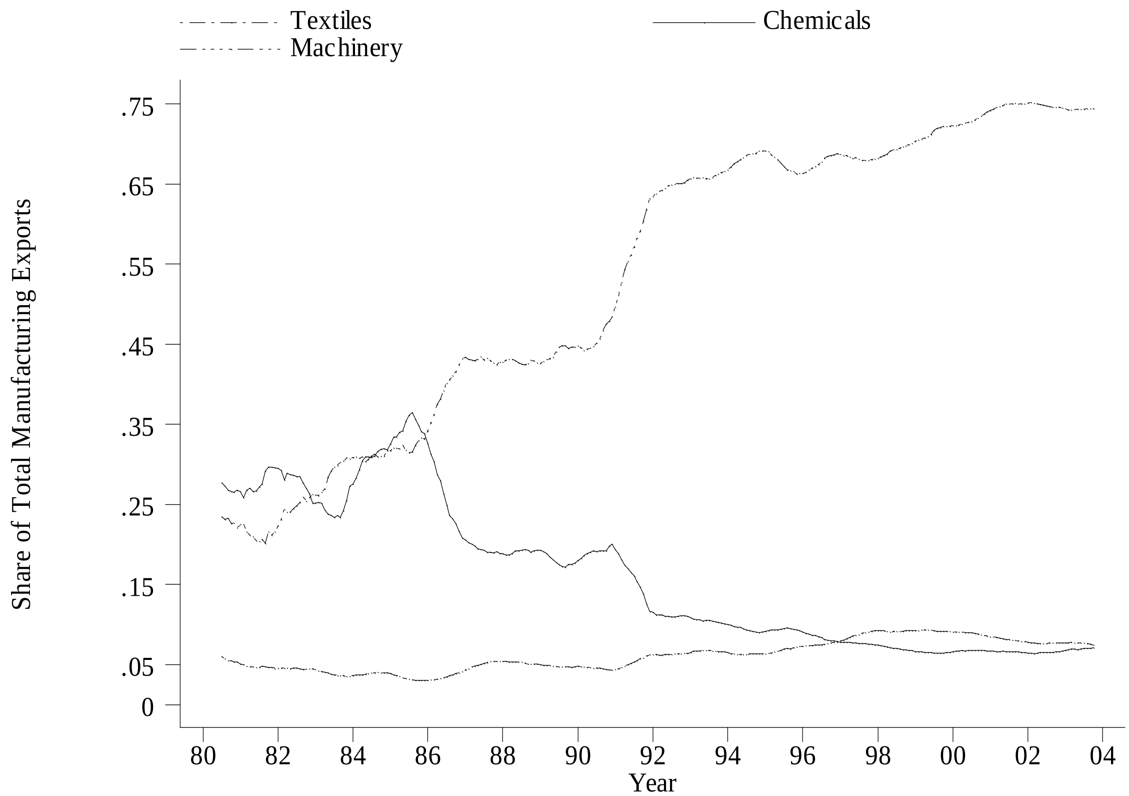
Figure 1: Mexican Industrial Export Shares



Notes: Data represent the 12-month moving average of each series. Textiles includes apparel. "Machinery" includes metal products and equipment. The discrete break 1991 in the export trends reported in Figure 1 occurs because prior to that year, maquiladora exports were not counted as exports.

Figure 2: Diagrammatic Representation of Lumpiness

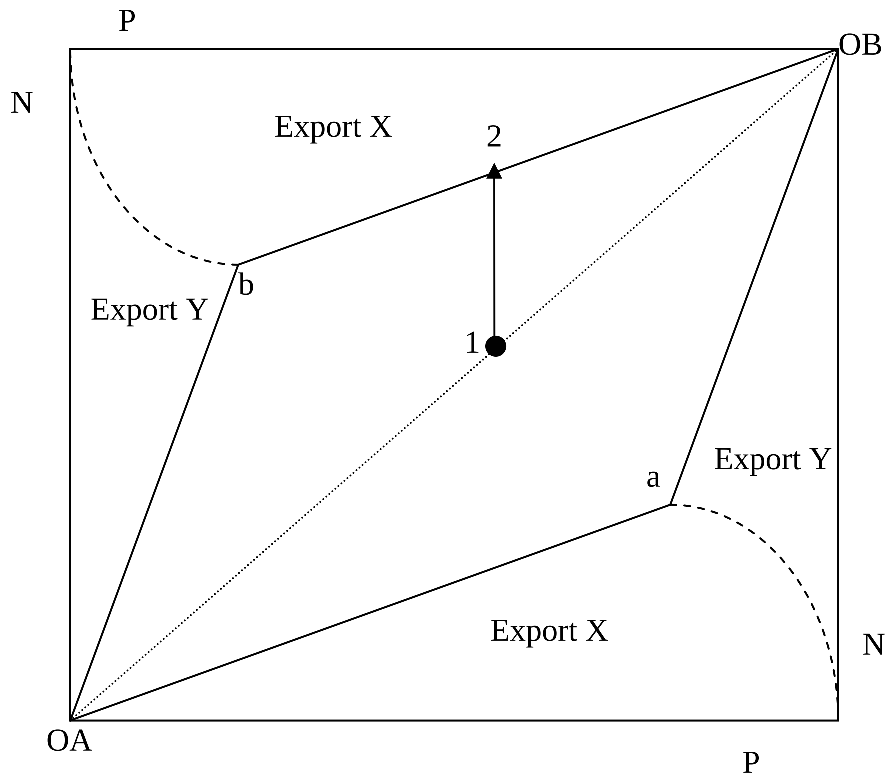


Figure 3: Lumpiness in a Multiple-Cone Equilibrium

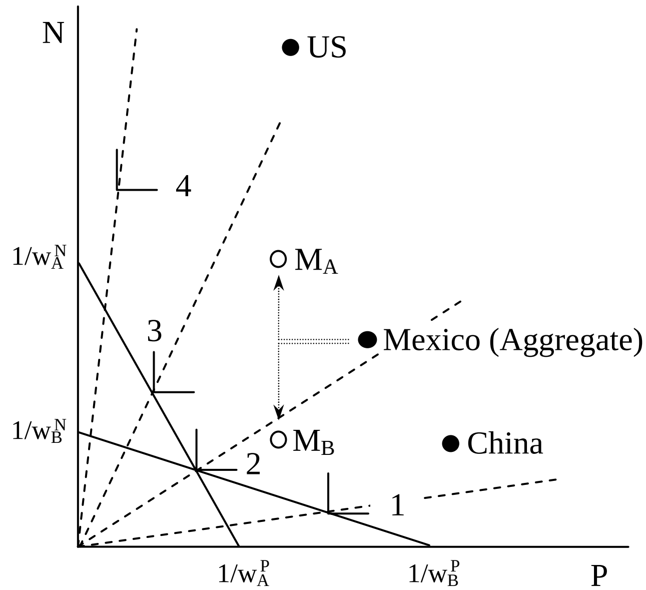


Figure 4: The States of Mexico

Figure 5: Maquiladora Employment by State in 2000

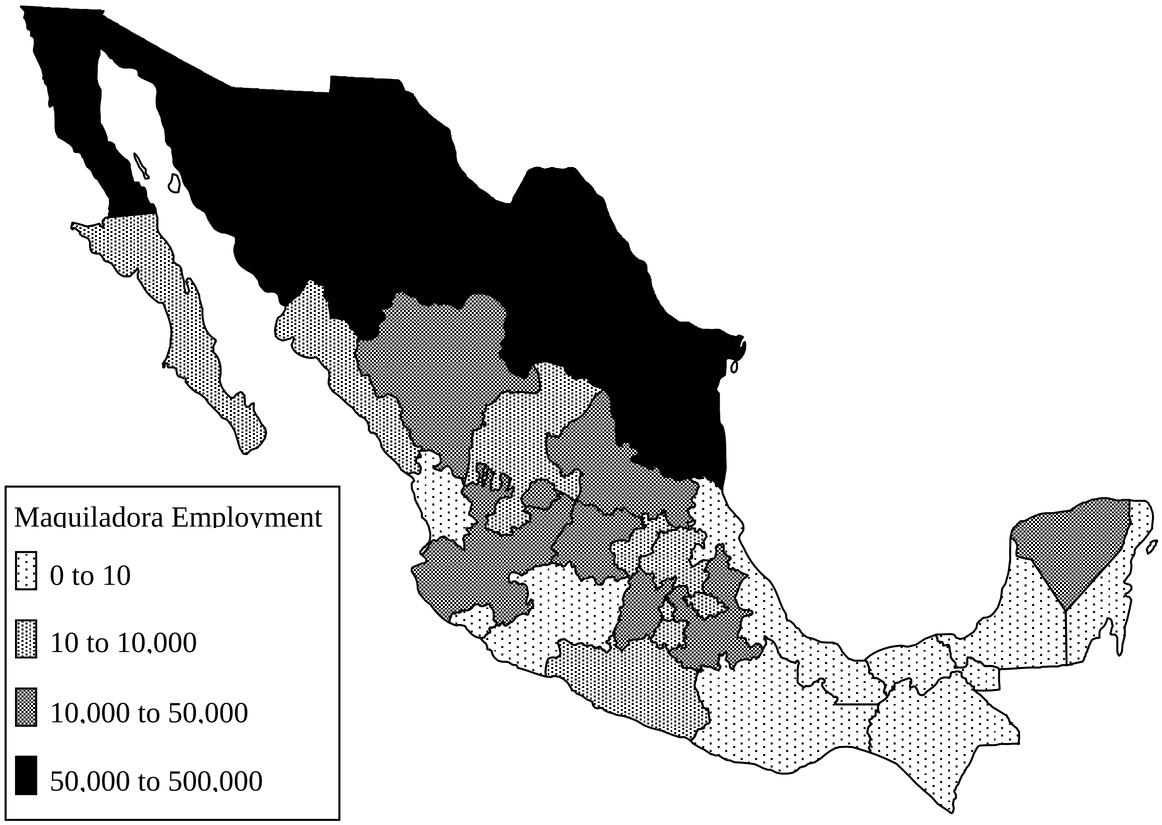


Figure 6: Maquiladora Establishments and Employment 1978-2003

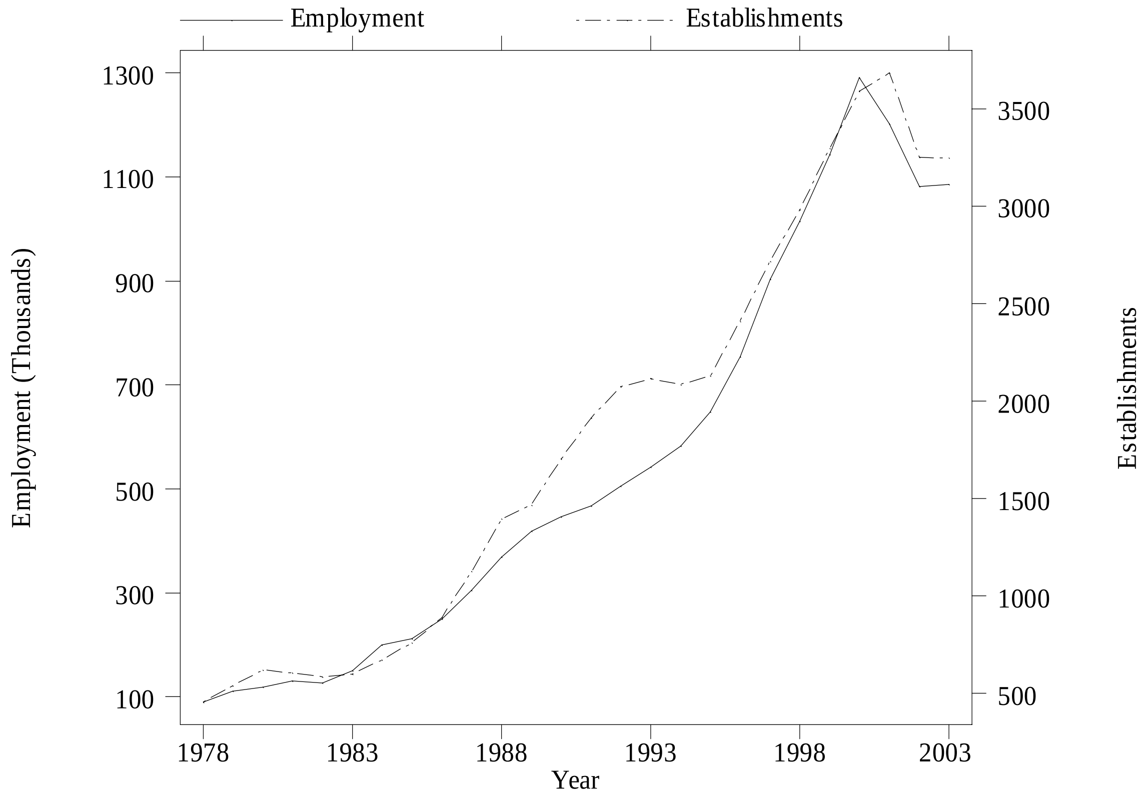


Table 1: Skill Intensity of Mexican Industries

			Average Wage (US$ per hour)		Average Education (years)		
Industry	Total Employment (1000)	Non-Production / Production Worker Ratio	Non-Production Workers	Production Workers	All Workers	Non-Production Workers	Production Workers
Paper/Printing	25,648	0.458	6.30	2.06	8.99	11.80	7.75
Chemicals	232,685	0.434	7.31	2.83	8.97	12.24	7.90
Food	448,303	0.401	6.88	2.22	7.69	11.68	6.88
Machinery	84,7634	0.354	6.64	2.33	8.55	12.14	7.90
Metals	19,238	0.341	7.02	2.51	9.18	12.38	8.07
Glass	52,295	0.278	7.56	2.22	7.43	11.81	6.62
Other	3,856	0.274	6.05	1.92	8.49	11.21	7.77
Wood	31,062	0.246	4.13	1.57	7.27	11.63	6.90
Textiles	305,411	0.207	4.31	1.93	7.40	11.39	6.97
Average	392,905	0.338	6.46	2.30	8.19	11.92	7.46

Notes: Total Employment and the ratio of non-production workers (N) to production workers (P) come from the 1986 Mexican Industrial Census (data from 1985). Average wages come from the *Encuesta Industrial Mensual* (because the Census does not have hours data) for 1988. Average education data come from the *Encuesta Nacional de Empleo Urbano* for 1988. The averages are simple averages (not weighted by production value). See Robertson (2004).

Table 2: Urban Population Shares

	1980	1985	1990	1995	2000
Mexico	66.4	69.6	72.5	73.4	74.4
Latin America	65.1	68.1	71.1	73.3	75.4
World	39.6	41.5	43.5	45.3	47.2
Europe	69.4	70.9	72.1	72.9	73.4
Less Dev. Regions	29.3	32.1	35.0	37.7	40.4
Africa	27.4	29.6	31.8	34.5	37.2
Asia	26.9	29.4	32.3	34.8	37.5

Notes: Data are from the United Nations Population Division World Population Prospects: The 2002 Revision to the Population Database (http://esa.un.org/unpp/sources.html). Categories are defined by the United Nations.

Table 3a: State Shares of Mexican Manufacturing Employment by Year

State	1986	1989	1994	1999
Aguascalientes	0.011	0.013	0.015	0.017
Baja California Norte	0.022	0.030	0.044	0.059
Baja California Sur	0.002	0.002	0.003	0.003
Campeche	0.002	0.002	0.003	0.002
Chiapas	0.005	0.007	0.008	0.007
Chihuahua	0.048	0.065	0.070	0.084
Coahuila	0.035	0.041	0.040	0.046
Colima	0.002	0.002	0.002	0.002
Distrito Federal	0.208	0.189	0.154	0.119
Durango	0.014	0.017	0.015	0.017
Guanajuato	0.042	0.045	0.050	0.055
Guerrero	0.005	0.005	0.008	0.009
Hidalgo	0.018	0.016	0.017	0.018
Jalisco	0.102	0.066	0.069	0.078
Mexico	0.153	0.144	0.133	0.117
Michoacan	0.018	0.021	0.021	0.020
Morelos	0.011	0.011	0.012	0.009
Nayarit	0.003	0.004	0.004	0.003
Nuevo Leon	0.076	0.078	0.077	0.077
Oaxaca	0.009	0.011	0.012	0.012
Puebla	0.042	0.042	0.049	0.054
Queretaro	0.019	0.019	0.019	0.002
Quintana Roo	0.002	0.002	0.003	0.011
San Luis Potosi	0.018	0.020	0.021	0.018
Sinaloa	0.012	0.010	0.012	0.010
Sonora	0.020	0.025	0.027	0.033
Tabasco	0.004	0.006	0.006	0.005
Tamaulipas	0.026	0.038	0.041	0.046
Tlaxcala	0.010	0.010	0.010	0.013
Veracruz	0.047	0.044	0.034	0.032
Yucatan	0.011	0.012	0.017	0.017
Zacatecas	0.002	0.003	0.005	0.006
Total Employment	2,576,775	2,640,472	3,246,042	4,184,682

Notes: Authors' calculations from the *Mexican Industrial Census*, various years. Totals may not sum to one due to rounding.

Table 3b: Number of Industries Producing in Each State

State	1986	1989	1994	1999
Aguascalientes	133	134	168	179
Baja California Norte	168	185	211	212
Baja California Sur	53	55	70	74
Campeche	60	55	63	78
Chiapas	78	84	101	130
Chihuahua	160	168	177	201
Coahuila	171	184	197	201
Colima	45	55	76	90
Distrito Federal	284	283	278	278
Durango	101	117	126	142
Guanajuato	191	192	211	220
Guerrero	72	74	101	110
Hidalgo	124	141	174	180
Jalisco	255	255	256	264
Mexico	271	272	270	269
Michoacan	165	157	188	189
Morelos	127	120	160	179
Nayarit	76	83	81	90
Nuevo Leon	243	249	243	252
Oaxaca	89	93	117	135
Puebla	220	217	231	236
Queretaro	35	31	50	80
Quintana Roo	45	37	58	86
San Luis Potosi	173	188	203	204
Sinaloa	110	114	142	158
Sonora	158	156	171	193
Tabasco	53	65	90	107
Tamaulipas	148	161	195	197
Tlaxcala	106	105	127	145
Veracruz	160	175	184	199
Yucatan	143	152	173	185
Zacatecas	76	73	95	106
Census Total	307	304	303	297

Notes: Authors' calculations from the *Mexican Industrial Census*, various years. Numbers represent the number of 6-digit manufacturing industries with positive employment in each year.

Table 4: Initial Estimation Results

	1986	1989	1994	1999
Aguascalientes	-0.212 (3.56)**	-0.190 (3.15)**	-0.249 (4.55)**	-0.293 (5.53)**
Baja California Norte	-0.350 (6.62)**	-0.363 (7.06)**	-0.345 (7.12)**	-0.364 (7.60)**
Baja California Sur	-0.344 (3.57)**	-0.489 (5.22)**	-0.393 (4.47)**	-0.394 (4.70)**
Campeche	-0.378 (4.03)**	-0.384 (3.95)**	-0.327 (3.45)**	-0.338 (3.83)**
Chiapas	-0.457 (6.07)**	-0.392 (5.24)**	-0.329 (4.87)**	-0.358 (5.59)**
Chihuahua	-0.153 (2.86)**	-0.160 (3.03)**	-0.103 (1.97)*	-0.155 (3.15)**
Coahuila de Zaragoza	-0.172 (3.37)**	-0.155 (3.06)**	-0.174 (3.48)**	-0.182 (3.71)**
Colima	-0.592 (5.91)**	-0.444 (4.71)**	-0.388 (4.70)**	-0.459 (5.82)**
Distrito Federal	0.218 (5.28)**	0.216 (5.16)**	0.210 (4.97)**	0.233 (5.56)**
Durango	-0.288 (4.31)**	-0.349 (5.48)**	-0.330 (5.28)**	-0.295 (4.86)**
Guanajuato	-0.330 (6.68)**	-0.297 (5.84)**	-0.307 (6.25)**	-0.303 (6.37)**
Guerrero	-0.606 (7.43)**	-0.645 (8.06)**	-0.585 (7.72)**	-0.605 (8.54)**
Hidalgo	-0.376 (6.36)**	-0.397 (6.91)**	-0.338 (6.39)**	-0.393 (7.53)**
Jalisco	-0.142 (3.24)**	-0.124 (2.80)**	-0.144 (3.27)**	-0.173 (4.03)**
Mexico	0.117 (2.75)**	0.119 (2.79)**	0.134 (3.12)**	0.117 (2.75)**
Michoacan	-0.474 (8.96)**	-0.421 (7.56)**	-0.528 (10.13)**	-0.588 (11.58)**
Morelos	-0.060 (0.98)	-0.232 (3.73)**	-0.247 (4.36)**	-0.241 (4.49)**
Nayarit	-0.344 (4.19)**	-0.514 (6.43)**	-0.568 (6.88)**	-0.577 (7.41)**
Nuevo Leon	0.079 (1.79)	0.067 (1.51)	0.059 (1.29)	0.047 (1.06)
Oaxaca	-0.526 (7.46)**	-0.531 (7.66)**	-0.526 (7.97)**	-0.529 (8.37)**
Puebla	-0.304 (6.53)**	-0.270 (5.71)**	-0.277 (5.93)**	-0.304 (6.65)**
Queretaro	0.027 (0.31)	0.016 (0.19)	-0.013 (0.15)	-0.056 (0.71)
Quintana Roo	0.029 (0.30)	0.001 (0.01)	-0.061 (0.67)	-0.137 (1.82)
San Luis Potosi	-0.256 (4.87)**	-0.215 (4.20)**	-0.206 (4.11)**	-0.290 (5.92)**
Sinaloa	-0.072 (1.11)	-0.154 (2.40)*	-0.137 (2.30)*	-0.188 (3.32)**
Sonora	-0.209 (3.80)**	-0.178 (3.23)**	-0.167 (3.13)**	-0.232 (4.61)**
Tabasco	-0.117 (1.35)	-0.091 (1.08)	-0.159 (2.07)*	-0.050 (0.72)
Tamaulipas	-0.267 (4.82)**	-0.242 (4.50)**	-0.237 (4.71)**	-0.277 (5.63)**
Tlaxcala	-0.185 (2.76)**	-0.169 (2.52)*	-0.221 (3.55)**	-0.261 (4.38)**
Veracruz	-0.151 (2.88)**	-0.211 (4.05)**	-0.166 (3.18)**	-0.237 (4.81)**
Yucatan	-0.255 (4.44)**	-0.314 (5.63)**	-0.240 (4.50)**	-0.243 (4.68)**
Zacatecas	-0.628 (7.85)**	-0.616 (7.60)**	-0.663 (9.01)**	-0.622 (8.78)**
Observations	4545	4623	5027	5271
R-squared	0.14	0.14	0.14	0.16

Notes: Results of estimating equation (5) for each year of the Mexican *Industrial Census* using OLS.

Table 5: Estimation Results
Excluding Mexico City and Mexico State

	1986	1989	1994	1999
Aguascalientes	-0.099 (1.59)	-0.083 (1.32)	-0.138 (2.41)*	-0.180 (3.25)**
Baja California Norte	-0.246 (4.45)**	-0.258 (4.78)**	-0.242 (4.80)**	-0.251 (5.02)**
Baja California Sur	-0.255 (2.53)*	-0.404 (4.11)**	-0.286 (3.11)**	-0.289 (3.30)**
Campeche	-0.309 (3.15)**	-0.286 (2.81)**	-0.233 (2.36)*	-0.224 (2.43)*
Chiapas	-0.073 (1.36)	-0.054 (1.02)	-0.076 (1.46)	-0.077 (1.51)
Chihuahua	-0.498 (4.74)**	-0.341 (3.44)**	-0.288 (3.35)**	-0.363 (4.41)**
Coahuila de Zaragoza	-0.349 (4.44)**	-0.280 (3.56)**	-0.222 (3.16)**	-0.250 (3.74)**
Colima	-0.053 (0.94)	-0.059 (1.05)	0.004 (0.07)	-0.055 (1.07)
Distrito Federal	----	----	----	----
Durango	-0.202 (2.89)**	-0.250 (3.73)**	-0.238 (3.65)**	-0.200 (3.15)**
Guanajuato	-0.224 (4.33)**	-0.187 (3.51)**	-0.202 (3.94)**	-0.198 (3.99)**
Guerrero	-0.538 (6.30)**	-0.555 (6.61)**	-0.490 (6.21)**	-0.515 (6.96)**
Hidalgo	-0.268 (4.34)**	-0.293 (4.86)**	-0.235 (4.27)**	-0.296 (5.42)**
Jalisco	-0.041 (0.90)	-0.018 (0.39)	-0.039 (0.85)	-0.067 (1.48)
Mexico	----	----	----	----
Michoacan	-0.364 (6.57)**	-0.310 (5.31)**	-0.430 (7.92)**	-0.484 (9.13)**
Morelos	0.035 (0.55)	-0.121 (1.85)	-0.146 (2.47)*	-0.135 (2.41)*
Nayarit	-0.276 (3.22)**	-0.443 (5.28)**	-0.474 (5.51)**	-0.482 (5.93)**
Nuevo Leon	0.179 (3.89)**	0.179 (3.85)**	0.155 (3.27)**	0.152 (3.28)**
Oaxaca	-0.427 (5.79)**	-0.441 (6.07)**	-0.417 (6.06)**	-0.414 (6.27)**
Puebla	-0.191 (3.92)**	-0.159 (3.22)**	-0.162 (3.32)**	-0.191 (4.01)**
Queretaro	0.147 (1.60)	0.134 (1.48)	0.100 (1.18)	0.055 (0.66)
Quintana Roo	0.113 (1.09)	0.097 (0.85)	0.055 (0.58)	-0.037 (0.46)
San Luis Potosi	-0.149 (2.72)**	-0.110 (2.06)*	-0.101 (1.92)	-0.182 (3.56)**
Sinaloa	0.012 (0.18)	-0.063 (0.94)	-0.043 (0.70)	-0.088 (1.49)
Sonora	-0.106 (1.84)	-0.075 (1.30)	-0.056 (1.01)	-0.122 (2.32)*
Tabasco	-0.025 (0.28)	-0.030 (0.34)	-0.064 (0.80)	0.052 (0.71)
Tamaulipas	-0.157 (2.71)**	-0.132 (2.33)*	-0.120 (2.29)*	-0.162 (3.16)**
Tlaxcala	-0.067 (0.95)	-0.050 (0.71)	-0.103 (1.59)	-0.135 (2.16)*
Veracruz	-0.049 (0.88)	-0.113 (2.07)*	-0.070 (1.29)	-0.138 (2.69)**
Yucatan	-0.143 (2.37)*	-0.193 (3.28)**	-0.128 (2.31)*	-0.133 (2.45)*
Zacatecas	-0.519 (6.20)**	-0.513 (6.03)**	-0.563 (7.33)**	-0.519 (7.01)**
N	3983	4062	4471	4717
R-squared	0.08	0.08	0.08	0.09

Notes: Results of estimating equation (5) for each year of the Mexican *Industrial Census* using OLS after excluding Mexico State and Mexico City.

Table 6: Production Structure Estimates

Dependent Variable: Number of Industries in Common

	(1) 1986	(2) 1989	(3) 1994	(4) 1999
$\lvert \hat{\alpha}_r^s \rvert$	-24.772	-32.300	-26.083	-28.037
	(5.266)**	(6.70)**	(5.61)**	(6.84)**
No. Ind. Producing in r (Ir)	0.432	0.453	0.505	0.521
	(34.081)**	(35.93)**	(38.84)**	(40.90)**
No. Ind. Producing in s (Is)	0.408	0.426	0.486	0.526
	(35.721)**	(36.95)**	(41.38)**	(46.70)**
Constant	-31.351	-33.705	-47.416	-53.537
	(11.760)**	(12.30)**	(15.75)**	(17.54)**
Observations	496	496	496	496
R-squared	0.83	0.84	0.86	0.88

Notes: $\lvert \hat{\alpha}_r^s \rvert$ is the absolute value of the difference between every regional pair's estimates of the coefficients shown in Table 4. Absolute value of t statistics in parentheses. *significant at 5%; **significant at 1%.

Table 7: Maquiladora Employment 1998

	Employment Share	N/P Employment Ratio	
State	**Maquila/Census**	**Census**	**Maquila**
Aguascalientes	0.286	0.261	0.041
Baja California Norte	0.868	0.153	0.078
Baja California Sur	0.226	0.319	0.031
Campeche	0.000	0.357	.
Coahuila	0.485	0.217	0.056
Colima	0.000	0.423	.
Chiapas	0.000	0.311	.
Chihuahua	0.742	0.152	0.084
Distrito Federal	0.004	0.506	0.108
Durango	0.340	0.17	0.052
Guanajuato	0.048	0.192	0.051
Guerrero	0.060	0.282	0.022
Hidalgo	0.008	0.186	0.069
Jalisco	0.087	0.323	0.126
Mexico State	0.020	0.352	0.121
Michoacan	0.000	0.308	.
Morelos	0.023	0.348	0.092
Nayarit	0.000	0.316	.
Nuevo Leon	0.142	0.285	0.090
Oaxaca	0.000	0.311	.
Puebla	0.101	0.198	0.047
Queretaro	0.552	0.422	0.083
Quintana Roo	0.000	0.299	.
San Luis Potosi	0.073	0.308	0.027
Sinaloa	0.022	0.401	0.148
Sonora	0.644	0.212	0.065
Tabasco	0.000	0.390	.
Tamaulipas	0.769	0.239	0.086
Tlaxcala	0.103	0.243	0.068
Veracruz	0.000	0.310	.
Yucatan	0.227	0.266	0.055
Zacatecas	0.154	0.326	0.070
Average	0.242	0.293	0.073

Notes: Maquilas include services as well as manufacturing. In 1998, and over the 1990-2003 period, services average 4% of total maquila employment. INEGI does not report data for all states, and we presume this reflects an insignificant number of maquiladoras and therefore enter "0" for these states. The employment ratio is the non-production/production worker ratio.