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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 both to undermine Mexico's aggregate labor abundance and to motivate behavior that is more consistent with relative skill abundance.

1. Introduction

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. This seminal paper sparked growing interest in testing for "lumpiness" both across and within developed and developing countries. Subsequent empirical work focuses on Deardorff's (1994) "lens condition," which requires factor endowments to vary less across countries than factor input intensities vary across goods. If the set of points (i.e. lens) defined by regional factor abundances passes outside the set of points defined by goods' factor intensities, factor price equality (FPE) is impossible and potentially unexpected behavior may emerge.

Demiroglu and Yun (1999), Xiang (2001), Qi (2003), Yun (2003), and Wong and Yun (2003) reveal that satisfaction of the lens condition, while necessary and sufficient for FPE in the two-factor, many-good, and many-country case, is necessary but not sufficient for FPE in settings with more than two factors. Thus, while violation of the lens condition may be useful for ruling out FPE, a lack of violation does not indicate support for FPE. Empirical results have been mixed. Debaere and Demiroglu (2003) show that lenses defined by country relative endowments pass outside lenses defined by the industries they produce. Debaere (2004) uses the lens condition to argue that regions within Japan, the United Kingdom, and India exhibit factor price equalization. Requena et al.'s (2008) study of Spain finds some evidence of lumpiness.

We use two approaches to examine factor lumpiness in Mexico. We first apply Deardorff's "lens condition" tests. We confirm Debaere's (2004) suggestion that ambiguity in the lens condition tests may be due to the influence of data aggregation on lens

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size. The lens condition is more likely to be satisfied when industries are relatively disaggregated compared to countries or regions because disaggregation increases lens size. Because the "true" relative level of aggregation is unknown, the outcome achieved by any particular level of relative aggregation is difficult to interpret.

We then apply a technique developed by Bernard et al. (2009) to test two of the key implications of lumpiness: whether relative factor prices are equal across the country's regions and whether regions within Mexico produce the same bundle of industries. We find that regional skill abundance and the relative skilled wage are negatively correlated across Mexican regions and that this variation is associated with product-mix specialization. These results are robust to variation in factor quality and the presence of *maquiladoras*.

Mexico offers an excellent environment in which to examine domestic lumpiness. Liberalizing early, Mexico has received a great deal of attention as a country that did not seem to follow the patterns suggested by Heckscher–Ohlin trade theory. First, between joining the GATT in 1986 and entering NAFTA in 1994, wage inequality increased in Mexico (Cragg and Epelbaum, 1996; Feenstra and Hanson, 1997; Revenga, 1997; Meza, 1999; Feliciano, 2000; Robertson, 2000, 2004; Esquivel and Rodriguez-Lopez, 2003; Verhoogen, 2008). Second, pre-liberalization tariffs were relatively high for labor-intensive goods and Mexico disproportionately reduced tariffs on labor-intensive products—seemingly puzzling behaviors given Mexico's assumed labor abundance (Hanson and Harrison, 1999). Finally, Mexico also seems to export its relatively skill-intensive goods. Before 1986, the year Mexico joined the GATT, more than half of the country's exports were in skill-intensive Chemicals and Machinery. These industries have the third and fourth highest average education levels and the second and fourth highest nonproduction to production worker ratios in Mexico. Exports of less-skill-intensive textiles, in contrast, were low.[1]

Regional differences within Mexico are stable and significant, suggesting geographic explanations might be relevant (Hanson, 1997; Chiquiar, 2008). In the language of trade theory, Mexico may be divided up into different diversification cones.[2] Sufficient regional concentration of skill may force 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.

This paper makes two additional contributions to the study of globalization. First, factor price inequality within a country casts further doubt upon the existence of factor price equality internationally.[3] Second, 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.

2. 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 nonproduction 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

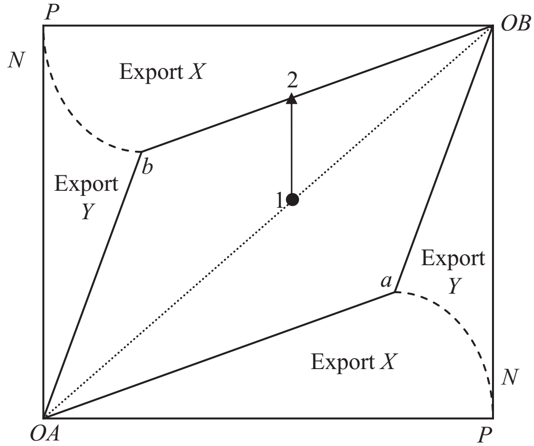

Figure 1. Diagrammatic Representation of Lumpiness

the relative goods price as given, and that factors do not move between regions within a country.[4] 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 1 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 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 FPE 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

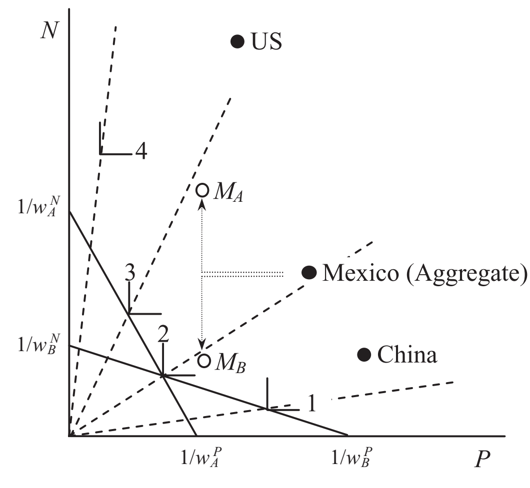

Figure 2. Lumpiness in a Multiple-Cone Equilibrium

model—a breakdown of relative FPE and concomitant differences in regional product mix—that we test for in the Mexican data.

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 2. 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 2 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 also be an exporter of relatively labor-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 the 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 (nominal) 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.

3. 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[6] Industrial Censuses, which provide data for the prior year. The Census contains information on the employment of production workers (*obreros*) and nonproduction workers (*empleados*), as well as aggregate payments to each type of worker (the wage bills).[7] The data classify Mexican industries using the *Clasificación 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). Table 1a shows the distribution of total manufacturing employment across states. In 1985, the central region of Mexico (Mexico City and Mexico State) had 36% of all manufacturing employment.[8] Table 1b reports the number of industries producing in the top and bottom four states in 1986. The number of industries is highest in Mexico State and Mexico City and lowest in Baja California Sur, Campeche, Queretaro, and Quintana Roo. Below, we test whether product mix overlap across regions coincides with equal relative factor rewards across regions.

4. The Lens Condition

Methodology

Deardorff's (1994) lens condition is based on Dixit and Norman's (1980) concept of an integrated world economy (IWE). An IWE equilibrium can be replicated—and FPE is possible—if factor endowments vary less across regions than factor intensities vary across goods. More formally, this condition requires the set of points defined by regional factor abundances to lie inside the set of points defined by goods' factor usage.

Results

Figure 3 reports separate lenses for six-, four-, three-, and two-digit CMAP industries and 32 Mexican regions for our most recent year, 1999.[9] Holding the region lens

Table 1a. State Shares of Mexican Manufacturing Employment by Year

State	*1986*	*1989*	*1994*	*1999*
Distrito Federal	0.208	0.189	0.154	0.119
Mexico State	0.153	0.144	0.133	0.117
Jalisco	0.102	0.066	0.069	0.078
Nuevo Leon	0.076	0.078	0.077	0.077
Campeche	0.002	0.002	0.003	0.002
Colima	0.002	0.002	0.002	0.002
Quintana Roo	0.002	0.002	0.003	0.011
Zacatecas	0.002	0.003	0.005	0.006
Total employment	2,576,775	2,640,472	3,246,042	4,184,682

Table 1b. Number of Industries Producing in Each State

State	*1986*	*1989*	*1994*	*1999*
Distrito Federal	284	283	278	278
Mexico State	271	272	270	269
Jalisco	255	255	256	264
Nuevo Leon	243	249	243	252
Tabasco	53	65	90	107
Colima	45	55	76	90
Quintana Roo	45	37	58	86
Queretaro	35	31	50	80
Census total	307	304	303	297

Notes: Authors' calculations from the Mexican Industrial Census, various years. Totals may not sum to one due to rounding. Numbers represent the number of six-digit manufacturing industries with positive employment in each year. The top and bottom four states in 1986 are shown to conserve space. Full results are available at the authors' websites.

constant, industry disaggregation increases the relative distance between industry and region lenses. Thus, while the lens condition is violated for two-digit industries, it is satisfied for three-, four-, and six-digit industries. A similar, yet starker, result emerges for 1986. Holding industry aggregation constant and increasing region aggregation renders satisfaction of the lens condition more likely in analogous fashion.[10]

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. (2009). 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

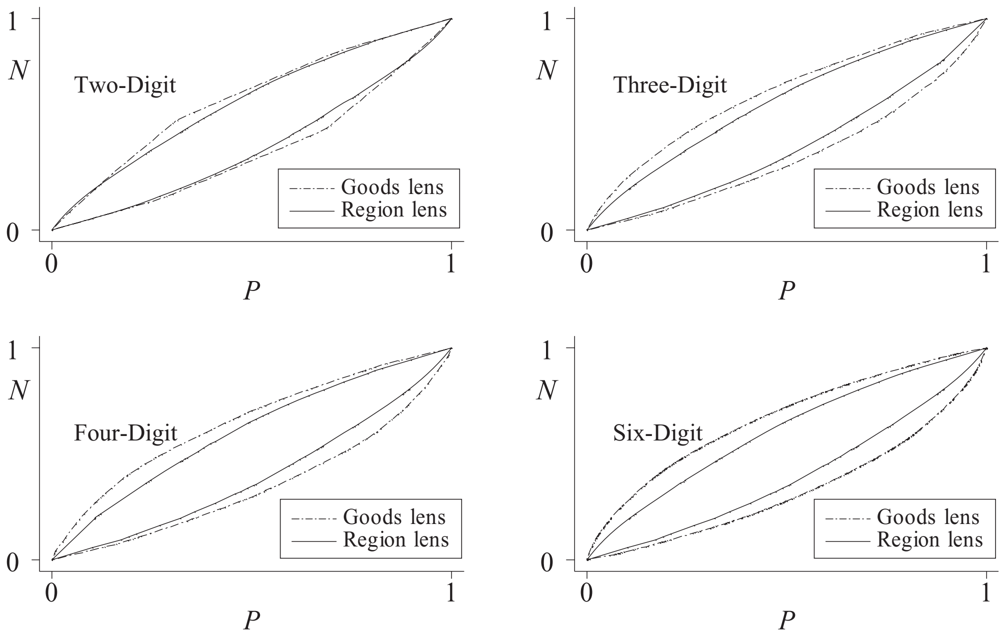

Figure 3. Mexican Industry and Region Lenses, 1999

Notes: *N* and *P* represent cumulative endowments (region lens) and use (industry lens) of skilled and unskilled workers, respectively. The region lens is comprised of the 32 states in each panel. The industry lenses are constructed from nine two-digit industries, 29 three-digit industries, 54 four-digit industries, or 314 six-digit industries, respectively.

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

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

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:

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

As noted in Bernard et al. (2009), multiplying observed factor prices (wages) by observed factor quantities (employment) generates the wage bill, which enables us to control for unobserved variation in factor quality. 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 nontradable amenities; see Courant and Deardorff (1993). 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 obtain:

$$\ln\left(\frac{RW_{rj}}{RW_{sj}}\right) = \sum_{r} \alpha_{r}^{s} d_{r} + \varepsilon_{rsj}, \tag{5}$$

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 analogue to finding that $\eta_{rsj} \neq 1$ and therefore is sufficient to reject the null hypothesis. Furthermore, as described by Bernard et al. (2009), positive estimated values of α_r^s imply lower relative wages for skilled workers in region r relative to region s.

5. Empirical Results

Baseline Estimates

We begin by defining region s to be the base region and we estimate (5) using all of Mexico as the base region. The base region relative wage for each industry is calculated by summing the wage bill for each of the two types of workers across all regions within an industry, and then dividing these sums. Each industry–region's relative wage 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 2 contains the initial results for each census year, with t-statistics noted in parentheses. 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 ("Distrito Federal") and Mexico State ("Mexico"). These two regions have the largest shares of manufacturing employment as well as the largest shares of skilled workers.

Table 2 also shows the results to be relatively stable across time periods. In all years, Mexico State and Mexico City are the only regions with positive and statistically significant coefficients. As well, the vast majority of the coefficients that are negative

Table 2. 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.
** Significant at the 5% level; *** significant at the 1% level.

and significant in 1985 are also negative and significant in 1999. The similarity of coefficients across time in Table 2 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, respectively. 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 2 is that they might be overly dependent on the presence of Mexico City and Mexico State. The overall results without these two regions (omitted to save space but available online) are very similar to those reported in Table 2. The relatively poor states (Oaxaca, Michoacan, Guerrero) remain near the bottom, and Nuevo Leon emerges at the top and the results are also stable across time.[11]

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.

Relative Wages and the Production Structure

The results in Table 2 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

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

where Z_{rs} represents the number of industries common to regions r and s and the final term represents a stochastic error. We redefine the superscript s to represent regions other than region r and then use the absolute differences between each pair of estimated $\hat{\alpha}_r^s$ coefficients from equation (5) to capture the estimated bilateral relative wage bill differences between each pair of regions. 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 3. 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 are correlated with the distribution of regional production. Based on the results in Table 2 for 1999, the estimated relative wage differences between Mexico City and Guerrero accounted for 23 fewer industries in common.

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

Table 3. 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 (I_r)	0.432	0.453	0.505	0.521
	(34.081)***	(35.93)***	(38.84)***	(40.90)***
No. ind. producing in s (I_s)	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 1%.

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 production workers. This gives us the quality-adjusted quantity ratio in each state–industry.

To adjust for worker quality, we use micro samples from the 2000 Mexican population census. These data cover the entire country. We start with the 10% sample (10,099,182 observations). From this universe, we keep all workers between 16 and 65 years (exclusive) and all workers who work for pay and are not self-employed. In the next step we 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 nonmanufacturing industries are aggregated to the two-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.

Our main hypothesis is that there is an inverse relationship between the (quality-adjusted) nonproduction/production quantity ratio and the (quality-adjusted) nonproduction/production wage ratio. In other words, areas with relatively more skilled workers have lower skilled-worker wage ratios. To test this hypothesis we regress the (quality-adjusted) wage ratio on the (quality-adjusted) quantity ratio. The estimated coefficient (standard error) is –0.284 (0.031), which is significant at the 1% level.[12] 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.

6. Conclusions

Inspired by Courant and Deardorff's (1992) theoretical insight that geographic concentration of factors within a country can influence countries' patterns of trade and production, this paper applies several techniques to explore the hypothesis of "lumpiness" in Mexico. A key consequence of factor lumpiness is significant variation in regional relative wages. 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 that experienced declining wage inequality following trade liberalization. It would also be worthwhile to investigate whether Mexico's exports are more skill-intensive than those from similarly endowed but less lumpy countries. This would allow one to compare which industries specifically overlap across countries with different endowments.

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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Notes

1. The full set of results are available online at the authors' websites. See http://www.macalester.edu/~robertson/Lumpy.html.
2. The word "cone" refers to the set of region endowment vectors that select the subset of industries in which regions specialize (Leamer, 1987).
3. Repetto and Ventura (1998), Davis and Weinstein (2001), Debaere and Demiroglu (2003), and Schott (2003) indicate that countries span multiple cones of diversification.
4. We address the empirical validity of this assumption later in the text.
5. We use Leontief production technologies in Figure 2 to keep the diagram simple. The same story can be told using technologies that allow for factor substitution.
6. More information about the Mexican Industrial Census can be found at http://www.inegi.gob.mx.
7. Using nonproduction 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 nonproduction workers, and that industries with a higher ratio of nonproduction workers also have higher average education levels.
8. This share falls over time, which Hanson (1997) notes and attributes to trade liberalization that shifts the focus of the market towards the border.
9. An alternative graphical presentation of the lens condition can be found in an online appendix on the authors' websites.
10. We do not demonstrate this sensitivity here because there is no natural grouping of Mexican states into "super" states. Disaggregating Mexican states into smaller geographic areas—which may more closely resemble the labor market areas implied by theory—increases region lens size and therefore increases the likelihood of finding a violation of the lens condition. We do not perform this exercise because confidentiality restrictions prohibit disclosure of results based on more disaggregate regional data.
11. 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.
12. The regression has 1183 observations and an adjusted-R^2 value of 0.065. Removing outliers, the estimated coefficient (standard error) is –0.214 (0.021), 1175 observations, and an adjusted-R^2 value of 0.078. When including industry controls, the estimated coefficient (standard error) is –1.162 (0.052) with an adjusted-R^2 value of 0.322.