Local-Labor-Market Effects of NAFTA: The Other Shoe Drops (PRELIMINARY AND INCOMPLETE)*

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Abstract

In previous work, we looked at the effect of US tariff reductions under NAFTA on US labor market outcomes, and found that blue-collar workers in industries and locations that lost tariff protection experienced slower wage growth compared to other workers. Here, we examine the corresponding reductions in Mexican tariffs on imports from the US. Surprisingly, we find that blue-collar workers in industries or locations whose Mexico tariffs fell also experienced slower wage growth compared to other workers. We tentatively suggest that the most plausible explanation for this finding is that the tariff reductions made it easier for US manufacturers to use offshoring to Mexico to lower costs.

JEL Classifications: F16, F13, J31.

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1 Introduction

NAFTA, perhaps the most important single change in US trade policy in the last two decades, went into force on January 1, 1994, and featured a phased schedule for the complete elimination of tariffs between the US, Mexico, and Canada. In previous work (Hakobyan and McLaren, 2016), we examined the effect on US workers of NAFTA's reductions in US tariffs on imports from Mexico. We used US decennial Census data from 1990 and 2000 to examine the effect on wage growth both by location and by industry. We found (i) the reduction in the tariff on industry i had a significant effect of lowering blue-collar wage growth for workers in industry i after controlling for personal characteristics; (ii) a reduction in the weighted average tariffs for a geographic location (weighted both by employment shares in that location and by Mexico's comparative advantage) was associated with a significant reduction in blue-collar wage growth for workers in that location, after controlling for industry of employment; and (iii) the latter effect holds even if the workers in traded-goods industries are removed from the sample, suggesting a spillover effect of reduced labor demand in tradables sectors pushing down blue-collar wages for non-tradeable service workers in the same location (or reduced local incomes pushing down the demand for local services). The effects were very heterogenous: All of these effects were small for the average worker and non-existent for college-educated workers but sizable and very deleterious for the most-affected blue-collar workers.

An important omission from that study is reductions in *Mexican* tariffs on *American* goods. Of course, that is the other shoe to drop; the point of the agreement is the exchange of reciprocal eliminations of trade barriers. In this paper we focus on the effects of those Mexican tariff reductions, again on US workers.

We had been expecting to find gains for workers employed in the most-affected industries or localities, as US exports are allowed to move more freely into Mexico. However, preliminary work has suggested a surprising pattern: The industries that saw the largest reductions in Mexico's tariffs on US goods saw *lower* US wage growth, other things equal. We will be working to explore this finding, and if it is robust, to try to interpret it.

The rest of the paper proceeds in the following way. Section 2 briefly explains the methodological framework developed in Hakobyan and McLaren (2016) and presents the basic results for the wage growth over 1990s. Section 3 explores several forms of spurious correlation as explanations for our basic results and Section 4 explores the possibility that the results are driven by increased ease of offshoring production tasks to Mexico.

2 Empirical approach and basic results

2.1 Data.

We use public-use anonymized Census samples from the IPUMS project at the Minnesota Population Center (www.ipums.org; see Ruggles et al, 2015). Selecting working-age employed workers gives us a sample size of 10,320,274 spread over the two years 1990 and 2000. The finest consistently-applied geographic identifier in the IPUMS data is the consistently-defined public-use microdata area, or 'conspuma.' A total of 543 non-overlapping conspumas cover the entire United States.

Mexican tariffs in 1991 and 1999 come from UN TRAINS data set. The imports from US to Mexico in 1991 are used as weights to aggregate the tariff data up to Census industry level. As in our earlier study, we follow a method similar to Topalova (2010), Kovak (2013) and Autor et al (2013) to identify a trade-generated local-labor-market shock at the conspuma level. Whether we are focused on US tariffs on Mexican goods or Mexican tariffs on US goods, we define a 'local average tariff' by averaging tariffs across industries with weights given by local employment shares and a measure of revealed comparative advantage. We explain those computations now.

Some account of comparative advantage is important in measuring trade policy because a tariff on an import from a given economy is irrelevant if that economy does not export that good. We compute Mexico's revealed comparative advantage RCA_M^j by:

$$RCA_M^j = \frac{\left(\frac{x_M^j}{x_{ROW}^j}\right)}{\left(\frac{x_M^{TOT}}{x_{ROW}^{TOT}}\right)},$$

where x_M^j is Mexico's exports of j to countries other than the US; x_{ROW}^j is the rest of the world's exports of j (that is, not the US or Mexico); and x_M^{TOT} and x_{ROW}^{TOT} are Mexican and rest-of-world exports of all goods, respectively. In other words, RCA_M^j is Mexico's share of industry j's exports, compared to Mexico's share of all exports. The US revealed comparative advantage in j, RCA_U^j, is defined analogously. We multiply the Mexican tariff on imports from the US in industry j with the US revealed comparative advantage in industry j, and *vice versa* for the US tariffs on Mexican goods to obtain what we call 'tariffs corrected for comparative advantage.'[1]

To obtain the local average tariff in a given conspuma, we take an average of the tariff on all industries, weighted both by the employment share of the industry in that conspuma, and the relevant revealed comparative advantage. We exclude agriculture from this calculation because the data do not tell us what crop or type of livestock the household raises, which is crucial to making any inference about trade policy; and we exclude workers in non-traded industries based on the reasoning developed in Kovak (2013).[2]

Table 1 shows summary statistics. Mexican tariffs on US goods (first two rows) were much higher than US tariffs on Mexican goods (rows 4 and 5) and also far more variable. The Mexican tariffs were also on a much slower path to elimination (a drop of 8.41% from a starting point of 12.87%) compared to US tariffs (a drop of 1.69% starting from 2.03%).

[1]We have experimented with other ways of weighting by revealed comparative advantage. We have redone the regressions without RCA adjustment, and also with a bilateral RCA adjustment. For the latter, the RCA measure is constructed using 1989 data from USITC on US exports to Mexico and the rest of the world, following the formula: (US exports to Mexico in industry j/US exports to ROW in industry j)/(US total exports to Mexico/US total exports to ROW). The results are essentially unchanged. Details are available on request.

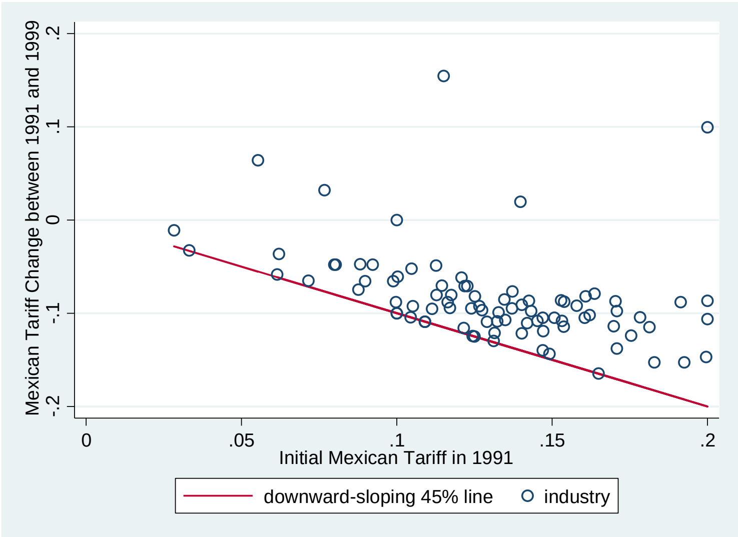
[2]The non-traded workers are excluded only from the calculation of the local average tariff. Those workers are in our dataset, however.

Table 1: Summary Statistics for Industry and Local Average US and Mexican Tariffs

Variable	Mean	St. Dev.	Min	Max	N
Mexican Tariffs					
Industry Tariff in 1991 (%)	12.87	3.95	0	20	88
Change in Industry Tariff (%)	-8.41	4.88	-16.48	15.48	88
Local Tariff in 1991 (%)	9.71	3.42	2.44	23.74	543
Change in Local Tariff (%)	-6.74	2.40	-17.17	-0.83	543
US Tariffs					
Industry Tariff in 1991 (%)	2.03	3.92	0	16.98	88
Change in Industry Tariff (%)	-1.69	3.36	-16.44	2.97	88
Local Tariff in 1991 (%)	0.49	0.41	.04	2.65	543
Change in Local Tariff (%)	-0.46	0.39	-2.59	-0.03	543
RCA-adjusted Mexican Tariffs					
Industry Tariff in 1991 (%)	16.42	27.49	0	224	88
Change in Industry Tariff (%)	-11.38	26.91	-224	54.48	88
Local Tariff in 1991 (%)	10.75	1.93	2.45	17.29	543
Change in Local Tariff (%)	-8.17	2.03	-12.72	3.23	543
RCA-adjusted US Tariffs					
Industry Tariff in 1991 (%)	0.99	1.98	0	8.79	88
Change in Industry Tariff (%)	-0.83	1.61	-6.86	0.13	88
Local Tariff in 1991 (%)	1.03	0.67	0.09	4.74	543
Change in Local Tariff (%)	-0.92	0.61	-4.28	-0.08	543

Notes: Industry level tariff variables are computed from 6-digit HS tariff data weighted by imports from the United States in 1991 and are mapped into 88 tradable goods industries based on Census industry classification. RCA is Mexico's or US's revealed comparative advantage in a particular industry as defined in the text. Conspuma level variables are weighted by employment in industries of a given conspuma. Tariffs on agricultural products are set to zero in all computations.

Figure 1: Mexican Industry Tariff in 1991 and Tariff Decline between 1991 and 1999



(RCA adjusted)

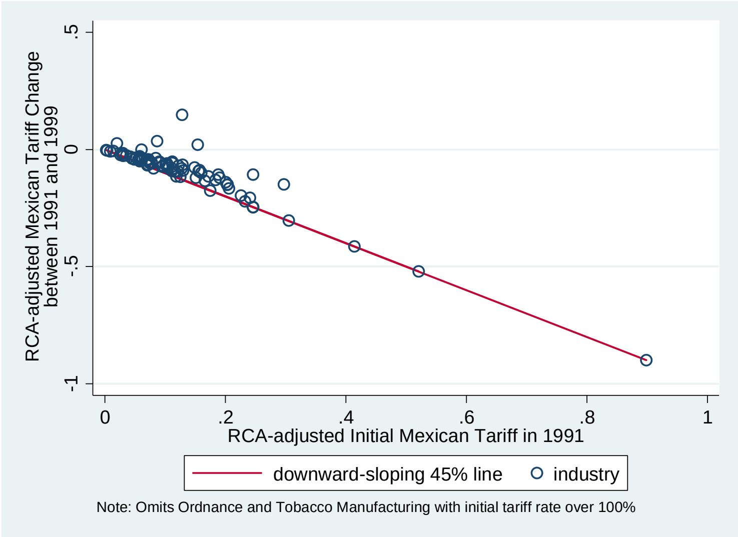
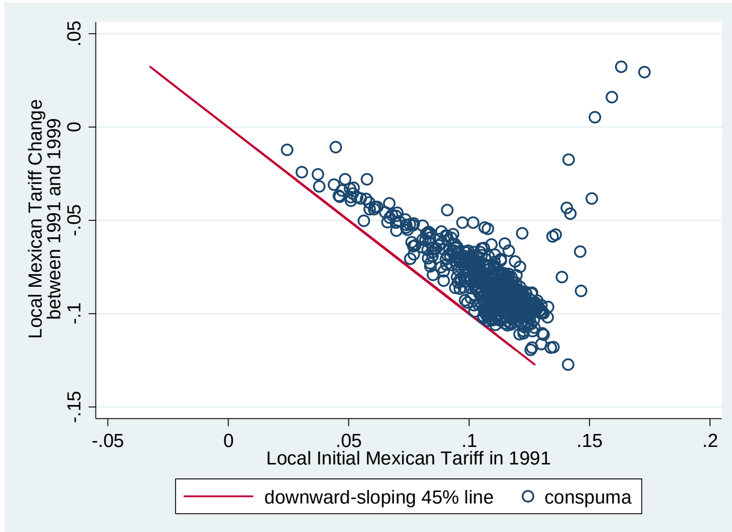


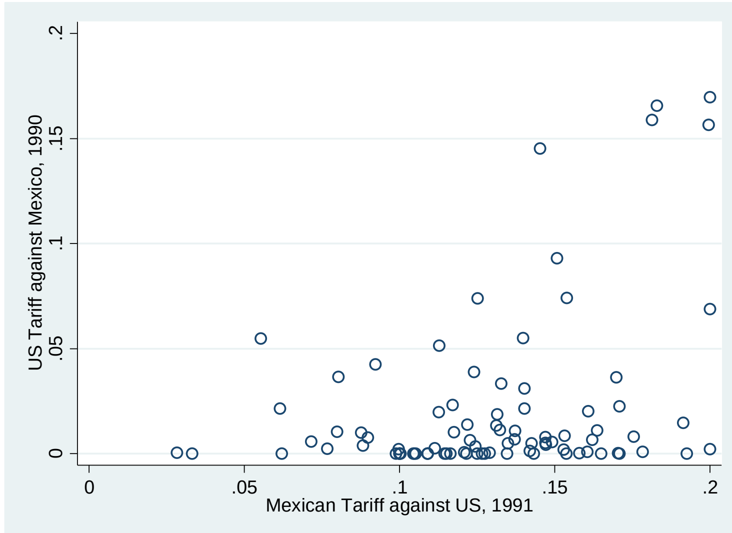
Figure 2: Local Mexican Tariff in 1991 and Tariff Decline between 1991 and 1999 (excludes agriculture)



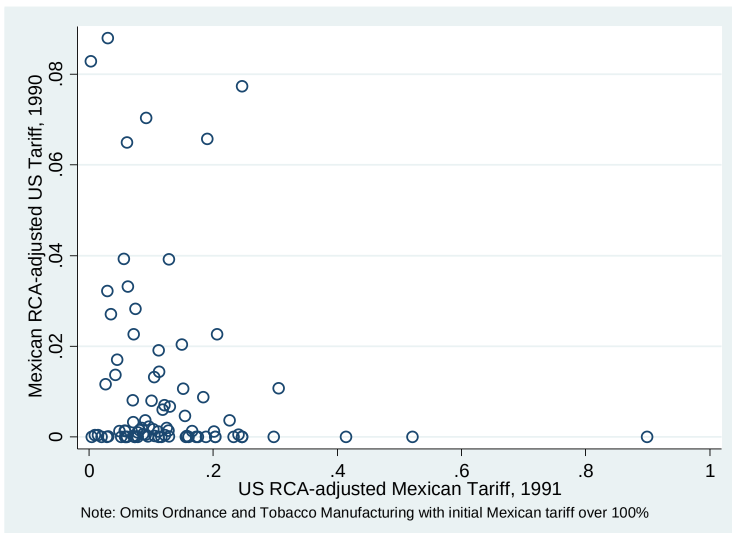
The same general observation holds for local average tariffs (rows 3, 4, 7, and 8) and for the comparative-advantage-corrected tariffs (last eight rows). Figure 1 shows the pattern of tariff adjustment for the Mexican tariffs by industry; raw tariffs are shown in the upper panel and comparative-advantage-adjusted tariffs in the lower panel. Each observation is an industry; the horizontal axis measures the initial tariff and the vertical axis the change between 1991 and 1999. The downward-sloping line is the 45-degree line. If a tariff was completely eliminated by 1999, the observation will sit on the line. Most industries sit above the line, some far above it, indicating a slow tariff elimination, and there is a great deal of variation in the pattern across industries. It is necessary to take account of this variation in our empirical method. Figure 2 shows the same pattern for the local average tariffs, where there is even more variation in timing.

Of course, both US and Mexican tariffs were changing at the same time under the agreement. Figure 3 shows the 1991 Mexico tariff in each industry on the horizontal axis and the 1990 US tariff for the same industry on the vertical axis. The top panel shows the raw tariffs, which are strongly positively correlated, and the bottom panel shows the comparative-advantage-corrected tariffs, which are negatively correlated due to the different trade patterns

Figure 3: Mexican vs. US Industry Tariffs



(RCA adjusted)



of the two economies.

2.2 Empirical approach.

If it is costly for workers to switch industries, then wage responses will be industry-specific, while if it is costly to move geographically, they will be location-specific. To account for both possibilities, for each worker we control both for the industry tariff and for the local average tariff. To account for a range of dynamic effects, we control separately for the initial tariffs and for the change in tariffs.[3] To allow for differences in the effect on different skill groups, we interact all of these variables with dummies for educational attainment (four categories, indexed by k below: high-school dropout; high-school graduate; some college; college graduate). This gives rise to an estimating equation as follows:

$$\begin{aligned}
log(w_i) &= \alpha X_i + \sum_j \alpha_j^{ind} ind_{i,j} + \sum_c \alpha_c^{conspuma} conspuma_{i,c} \\
&+ \sum_{k \neq col} \gamma_{1k} educ_{ik} + \sum_k \gamma_{2k} educ_{ik} yr2000_i \\
&+ \sum_{k \neq col} \delta_{1k} educ_{ik} loc\tau_{1991}^{c(i)} + \sum_k \delta_{2k} educ_{ik} yr2000_i loc\tau_{1991}^{c(i)} \\
&+ \sum_{k \neq col} \delta_{3k} educ_{ik} loc\triangle\tau^{c(i)} + \sum_k \delta_{4k} educ_{ik} yr2000_i loc\triangle\tau^{c(i)} \\
&+ \sum_{k \neq col} \theta_{1k} educ_{ik} RCA^j \tau_{1991}^{j(i)} + \sum_k \theta_{2k} educ_{ik} yr2000_i RCA^j \tau_{1991}^{j(i)} \\
&+ \sum_{k \neq col} \theta_{3k} educ_{ik} RCA^j \triangle\tau^{j(i)} + \sum_k \theta_{4k} educ_{ik} yr2000_i RCA^j \triangle\tau^{j(i)} \\
&+ \mu Border_{c(i)} yr2000_i + \epsilon_i,
\end{aligned} \tag{1}$$

where $j(i)$ is the industry of employment of worker i; $ind_{i,j}$ is a dummy variable that takes a value of 1 if worker i is employed in industry i; $yr2000_i$ is a dummy variable that takes a value of 1 if worker i is observed in the year 2000;[4] $conspuma_{i,c}$ is a dummy variable that takes a value of 1 if worker i resides in conspuma c; $c(i)$ is the index of worker i's conspuma; $loc\tau_{1991}^{c(i)}$ is the local average for conspuma $c(i)$ of Mexican tariffs on US goods in the initial year 1991; $loc\triangle\tau^{c(i)}$ is the change in that local average tariff between 1991 and 1999; $RCA^{j(i)}\tau_{1991}^{j(i)}$ is the US revealed comparative advantage in industry $j(i)$ multiplied by the tariff imposed by Mexico on imports of industry $j(i)$ from the US in the initial year 1991; $RCA^j\triangle\tau^{j(i)}$ is the

[3]There are a variety of reasons controlling for initial tariffs can be called for. For example, if an industry initially had a 10% tariff and saw a reduction of 2% between 1990 and 2000, as of 2000 workers would be expecting an additional 8% reduction as the agreement is fully phased in. This would not the be case for an industry with an initial 2% tariff that saw a 2% reduction between 1990 and 2000; as of 2000 the tariff elimination for that industry would be complete. These different expectations can have a large effect on wages, as shown with a theoretical model in Artuç et al (2008), and controlling for the initial wage can capture these effects. Whatever the reason behind it, in our previous study we found that controlling for initial tariffs is important in practice.

[4]Because of the nature of the sample, we are unable to observe any worker at more than one date.

change in this protection measure between 1991 and 1999; and $border_{c(i)}$ is a dummy variable that takes a value of 1 if worker i lives in a conspuma on the US-Mexican border.

The parameters of primary interest here are $\delta_{2,k}$ and $\delta_{4,k}$, which measure the initial-tariff effect and the impact effect, respectively, for the local average tariff for educational class k; and $\theta_{2,k}$ and $\theta_{4,k}$, which measure the initial-tariff effect and the impact effect, respectively, for the industry tariff. Their difference is also of interest: If a conspuma faced an initial local average Mexican tariff equal to $\bar{\tau}$ which was completely eliminated by the year 2000, then the overall effect on wage growth for workers of educational class k in that conspuma would be $(\delta_{2,k} - \delta_{4,k})\bar{\tau}$. Similarly, if an industry faced an initial Mexican tariff of $\tilde{\tau}$ which was completely eliminated by 2000, the effect on workers of educational class k in that industry would be $(\theta_{2,k} - \theta_{4,k})\tilde{\tau}$.

2.3 Basic results.

Running this regression produces the results in Table 2 column (1), which shows for convenience the values $(\delta_{2,k} - \delta_{4,k})\bar{\tau}$ and $(\theta_{2,k} - \theta_{4,k})\tilde{\tau}$ for all four educational classes. Surprisingly, they are all negative, and all significant except for workers with a college degree. This implies that, at least for a blue-collar worker in the US, elimination of Mexico's tariffs against the goods produced by that worker's industry or by industries in that worker's location *lowered* that worker's wage growth over the decade of the agreement's implementation. The effect is negligible and insignificant for college graduates but sizable and highly significant for all other workers. Column 2 of the table shows the result when only workers in non-traded industries are included in the regression. The same effect is apparent.

This is the finding we wish to understand. It appears to imply that not only did a worker in an industry or a town that lost its tariff against Mexican imports suffer slower wage growth – as indicated in our earlier study, easily understood by basic theory and consistent with other empirical studies – but that workers in an industry or town that *gained improved access* to the Mexican market *also* suffered slower wage growth. The following sections attempt to

Table 2: Differences Between Initial-tariff and Impact Effects

	Full sample (1)	Non-tradable sectors (2)
Location Effect		
Less than high school	-1.906***	-1.621***
High school graduate	-1.237***	-1.293***
Some college education	-1.279***	-1.25***
College graduate	0.032	0.096
Industry Effect		
Less than high school	-0.199***	
High school graduate	-0.11***	
Some college education	-0.096***	
College graduate	-0.0738	
N of Observations	10,320,274	7,489,403

Notes: The table reports the overall impact on wages (computed as a difference between initial-tariff and impact effect) and its significance for each education group when a US location or industry gains duty free access to Mexican market within the sample period. *** indicates significance at the 1% level. Agricultural tariffs are set to zero in all regressions.

understand this finding.

3 Possible spurious correlations.

This surprising result may be explained by any one of a number of theories. Here we review some reasons the result may be picking up a correlation with omitted variables.

Correlation with US tariffs. The most obvious possibility is that the tariffs that are falling in Mexico are correlated with tariffs in the US, which are falling at the same time, and perhaps this regression is picking up the effects of those US tariff reductions. Indeed, the tariffs tend to be positively correlated, as noted earlier. However, we are interested in tariffs adjusted for revealed comparative advantage, and, as Figure 3 shows, because of the differences between the two economies, those adjusted tariffs are *negatively* correlated.

To check the possibility that such a correlation could be driving our results, we add the US tariffs to the regression as in our earlier study. The third column of Table 3 shows the result; the second column shows the result of including *only* the US tariffs, as in our earlier paper, for comparison. It is clear that including the US tariffs does not qualitatively change either the result of Table 3 or the results of our earlier study.

Endogeneity of tariffs. One might wonder if the decision to decrease a given tariff more quickly than another may have been affected by economic conditions. Notwithstanding that there are no obvious reasons the Mexican tariff change should be affected by local labor market conditions in the US, it may be worth exploring. Kowalczyk and Davis (1998) find that Mexican tariff phase-outs cannot be explained by Mexican protection, and are correlated with U.S. tariff phase-outs, so we instrument Mexican initial tariffs (and change in tariffs) with US initial tariffs (and change in tariffs), reporting the results in column 4 of Table 3. The results are similar, somewhat smaller for some coefficients and somewhat larger for others.

The rise of China. The period in question coincided with the first wave of increased manufacturing exports from China. Although the major expansion of Chinese manufactured exports occurred later, after China joined the WTO (Pierce and Schott (2016), Autor, Dorn, and Hanson (2013)), the incipient rise of exports during the 1990's is another plausible explanation for our surprising result. Perhaps the expanding export opportunities for US industries after the launch of NAFTA did not have the expected effect on US workers' wages because US exports were crowded out by Chinese exports, and perhaps these exports occurred precisely in the industries that had been most protected in Mexico. To examine this possibility, we control explicitly for imports from China to Mexico, by including in the regression (i) the change in the share of imports for each industry that comes from China, and (ii) the employment-weighted local average of this change for each conspuma interacted with the education class and year-2000 dummies. The results are listed in Column 5 of Table 3. Clearly, the results remain qualitatively the same although smaller in magnitude.

Having checked for various forms of spurious correlation as the source of our result, we now examine a possible explanation: Interaction of tariff reductions with offshoring.

Table 3: Differences Between Initial-tariff and Impact Effects

	Mexican tariff measures	US tariff measures	Both US and Mexican tariffs	Instrument Mexican tariffs with US tariffs	Control for change in Mexico's Chinese imports share
	(1)	(2)	(3)	(4)	(5)
Mexican Tariff Measures					
Location Effect					
Less than high school	-1.906***		-1.833***	-1.467***	-1.79***
High school graduate	-1.237***		-1.204***	-1.196***	-1.212***
Some college education	-1.279***		-1.207***	-1.23***	-1.214***
College graduate	0.032		0.094	0.034	0.089
Industry Effect					
Less than high school	-0.199***		-0.174**	-0.413***	-0.177**
High school graduate	-0.11***		-0.103***	-0.217**	-0.103***
Some college education	-0.096***		-0.09***	-0.215	-0.091**
College graduate	-0.074		-0.077*	-0.046	-0.08
US Tariff Measures					
Location Effect					
Less than high school		-2.120***	-1.67***	-2.18***	-2.02***
High school graduate		-0.917**	-0.609	-0.835**	-0.355
Some college education		-1.540***	-1.062*	-1.315**	-0.856
College graduate		-0.936	-0.957	-0.899	-0.808
Industry Effect					
Less than high school		-2.111***	-1.817***	-2.128***	-1.745***
High school graduate		-1.214***	-0.974**	-1.343***	-0.99**
Some college education		-1.418***	-1.045**	-1.491***	-1.049**
College graduate		-0.297	0.133	-0.299	0.081

Notes: N=10,320,274. The table reports the overall impact on wages (computed as a difference between initial-tariff and impact effect) and its significance for each education group when a US location or industry gains duty free access to Mexican market and loses all of its protection between 1990 and 2000. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively. Agricultural tariffs are set to zero in all regressions.

4 Can offshoring explain the result?

Our industry categories, from the Census, are necessarily crude; for example, industry 342 is ‘Electrical Machinery, Equipment, and Supplies.’ This includes both finished products such as a lathe, and their components, such as the motor or the switches that are used to assemble the lathe. Suppose that a lathe is built of a number of manufactured components which all must be assembled in the same place. Suppose that under the initial tariff regime the cost-minimizing way for an American firm to produce the lathe is to assemble it in the US to avoid Mexican tariffs on components moving across the border, but with the reduction of the Mexican tariff it becomes cost-efficient to relocate assembly in Mexico. This would be a case in which a reduction in Mexico’s tariffs on imports of industry 342 from the US would reduce the demand for labor within industry 342 in the US – unless the resulting cost reduction for the manufacturing process causes an expansion of the industry so dramatic as to outweigh the loss of assembly work to Mexico. We investigate the plausibility of these explanation in this section.

4.1 Some background on offshoring to Mexico.

Offshoring of industrial production from US firms to Mexican locations long pre-dates NAFTA. In 1965, the Mexican government initiated the Border Industrialization Program (BPI) (Eaton, 1997, p. 757). This provided for manufacturers to import inputs or partially-finished products into facilities in northern Mexico duty-free and process for export. Plants that operated under this regime are known as ‘maquiladoras.’

The BPI program on the Mexican side was complemented on the US side by Chapter 98, subchapter 2, of the Harmonized Tariff Schedule, enacted in 1964 (USITC 1999). Under this program, imports of goods produced abroad partly with US-made inputs are subject to tariff only on the foreign value-added. Both the BPI regime and the US HTS 9802 rules applied for any trade partner country, but in practice they were overwhelmingly most used by US manufacturers offshoring to Mexico, particularly in the automotive, apparel, and television industries. For example, Mexico accounted for 41% of US imports under HTS 9802 in 1996, of which the estimated US-originated content was estimated at 52% (Hornbeck 1998, pp.2-3).

Despite the advantages the maquiladora program offered, there were costs to using it as well. For most of the life of the program, a maquiladora plant was required to be located within 10 kilometers of the US border (USITC 1999, p.2-1), a policy designed to promote industrial development in what had been a sparsely-populated region with high unemployment rates (Vargas 1999, p.3). This geographic constraint would of course not be a costly constraint or even a binding constraint for all firms, but others may need to locate elsewhere for reasons of infrastructure or personnel. Maquiladora plants were required to export all of their output; selling even a single unit to Mexican consumers would violate the rules of the program. Firms were required to post a bond on import of inputs, as a guarantee that all production would be used only for exports (Eaton, 1997, p.756). It was common for maquiladora plants to be structured as two separate firms, one that would do the production and a second one, called a 'shelter,' that would handle the administrative burden (both separate from the US client) (Eaton, 1997, pp.757-8).

As a result, even though in principle the Mexican tariff on inputs would not matter for US-bound manufactures, in practice it is quite possible that some offshoring activities would incur the tariff cost,[5] and so Mexican tariff rates would be relevant for US offshoring decisions.[6] In the following section we develop a simple model to illustrate how that may possibly affect US workers in the paradoxical way indicated in our regression results above. In that model, to keep things simple, we ignore the maquiladora sector *per se*, despite its importance, in order to focus on the comparative statics of non-maquiladora production, where the Mexican tariffs are directly relevant. A fuller model would include both.

[5]Eaton (1997) has an extensive discussion of relative costs between maquiladora and non-maquiladora operations in Mexico and how they changed under NAFTA.

[6]This is analogous to exporters choosing not to make use of duty-free access under the Generalized System of Preferences (see, for example, Hakobyan (2015)) or under a trade agreement (see, for example, Kunimoto et al (2005)). In those cases, the costs of duty-free access come in the form of rules of origin and administrative burdens.

4.2 A simple model.

Consider a world with two countries, the US and Mexico. Each economy has two industries, X and Y, each producing homogeneous output with constant returns to scale. The Y industry produces output using labor alone with a constant unit marginal product of effective labor. Letting Y output be the numeraire, the price of X output will be denoted as p.

Each unit of good X requires one unit each of a continuum of tasks to be completed. The tasks are indexed by $z \in [0, 1]$. Task z requires labor and capital to complete, and $c^z(w, r)$ denotes the minimum cost of completing one unit of the task, where w is the price of one unit of effective labor and r is the price of a unit of capital services. The US has exogenous endowments of labor and capital equal to L and K respectively, while in Mexico the endowments are L^* and K^*. Assume that $\frac{L}{K} < \frac{L^*}{K^*}$.

We make a distinction between nominal and effective units of labor. Each worker has an idiosyncratic productivity a^i in industry i. These productivities can be thought of as generated by a probability distribution that is iid across workers and industries. Let the price of effective labor in industry i be w^i in the US and w^{i*} in Mexico, which in equilibrium will be the marginal value product of effective labor. Given our normalization, $w^Y \equiv 1$, so we henceforth drop the superscript and write w for w^X and w^* for w^{X^*}. Each US worker will chose to work in X if for that worker $a^X w > a^Y$ and will work in Y otherwise. Aggregating these decisions gives rise to an effective US labor supply for the X industry denoted by $E^X(w)$, and analogously $E^{X*}(w^*)$ for Mexico.[7]

Any firm producing X can locate any task either in the US, where it will be performed with US labor and capital, or in Mexico, where it will be performed with Mexican labor and capital. Tasks must be completed in sequence, so that if $z < z'$, task z must be completed before task z'. In the language of Baldwin and Venables (2013), the production process

[7] This way of modeling the labor market is sometimes called a 'Roy' model or an 'assignment' model, and is a useful way of creating a friction between industries so that a rise in labor demand in one industry is accompanied both by a rise in that industry's wages and that industry's employment. See Costinot and Vogel (2015) for a survey.

is a ‘snake.’ In addition, similar to Feenstra and Hanson (1996), the tasks are ranked by labor intensivity, so that for any w and r, $\frac{c_1^z(w,r)}{c_2^z(w,r)} < \frac{c_1^{z'}(w,r)}{c_2^{z'}(w,r)}$, where a subscript denotes partial derivatives so the inequality compares the labor-capital ratio used across tasks. We will focus on equilibria where, because the US is capital abundant, $\frac{w}{r} > \frac{w^*}{r^*}$, and so the cost of performing a task in the US relative to performing it in Mexico rises with z.

As a result of this production structure, offshoring some tasks to Mexico requires performing in the US tasks up to a cutoff, say, $\bar{z}$, shipping the partly-completed goods to Mexico, and completing the remaining $1 - \bar{z}$ tasks there. Such partially-completed goods crossing the border incur an *ad valorem* tariff, τ, which is assessed on the unit cost of the accumulated production to that point. The tariff will thus be paid on production costs embodied in tasks 0 through $\bar{z}$, unless all of the production is done in the US with no offshoring, which is equivalent to setting $\bar{z} = 1$. There is, therefore, a trade-off for any X producer: Offshoring reduces the production costs by allowing more labor-intensive later assembly tasks to be done in labor-abundant Mexico, but it requires the Mexico tariff to be paid on the partially-finished goods at the border. We will focus on equilibria in which a portion of the X production is done with offshoring and a portion without, and prices adjust to make each producer indifferent between the two options. We will denote by K^O the portion of US capital that is used to produce with offshoring.

The story. With these elements of the model in place, it is easy to see how a reduction in Mexico’s tariff τ on X-industry products could lower the US X-industry wage. The reason is that such a tariff reduction lowers the cost of firms that offshore a portion of their production to Mexico. This tends to increase K^O, which then lowers the demand for US workers in the X industry. This can be thought of as the extensive-margin effect. At the same time, for those firms that do use offshoring, the cost reduction applies only to the portion of the production process that is performed in the US, so they will tend to offshore a smaller portion of their production process than they did before the tariff reduction. In other words, they will increase $\bar{z}$. This will have the effect of *raising* the US demand for labor in industry X, and can be thought of as the intensive-margin effect. If the extensive-margin effect is stronger than the intensive-margin effect, US X-industry wages will fall. We will construct an example below in which the extensive-margin effect dominates; whether it does so in practice or not is an empirical question.

Note that the nature of the cost change is different here from other studies of offshoring. Other studies (for example, Grossman and Rossi-Hansberg's (2008) theoretical model, Antras, Fort and Tintelnot (forthcoming), and Artuç and McLaren (2015)) all look at a change that lowers the cost of the foreign-supplied inputs or production tasks. Such a change encourages substitution within the firm away from domestic inputs and domestically-performed tasks. But here we are looking at a reduction in the cost of a *domestic* task or input, because the Mexican tariff applies only to those portions of the production chain performed in the US. This reduction in costs works in the opposite direction, encouraging substitution of US-performed tasks for Mexican ones, and thus an increase in $\bar{z}$. Nonetheless, due to the extensive-margin effect, this change in tariff can still have a negative effect on US wages in the affected industry.

To see these relationships, we need the equilibrium conditions.

4.2.1 Equilibrium conditions.

First, the cutoff $\bar{z}$ is determined by the condition:

$$(1+\tau)c^{\bar{z}}(w,r) = c^{\bar{z}}(w^*,r^*). \tag{2}$$

Clearly, $\bar{z}$ is decreasing in w and τ and increasing in w^*. Note that since the tasks become more labor-intensive as z increases, the ratio of the cost of a task in the US to the cost in Mexico will rise with z as well. For any $\xi > 0$ we can write the fraction of tasks with $\frac{c^z(w,r)}{c^z(w^*,r^*)} < \xi$ as $G(\xi; w, r, w^*, r^*)$, which is an increasing function of ξ with partial derivative with respect to ξ denoted $g(\xi; w, r, w^*, r^*)$. Condition (2) can then be written:

$$\bar{z} = G\left(\frac{1}{1+\tau}; w, r, w^*, r^*\right). \tag{3}$$

Note that for any change in factor prices or in τ, the derivative of $\bar{z}$ with respect to that variable will be proportional to $g\left(\frac{1}{1+\tau}; w, r, w^*, r^*\right)$. Generally, any increase in the dispersion of labor intensivities across tasks will result in lower values of $g\left(\frac{1}{1+\tau}; w, r, w^*, r^*\right)$. For example, if task $z = 0$ uses hardly any labor and task $z = 1$ uses hardly any capital and the labor-capital ratios are evenly distributed between those extremes, g will take low values throughout; while if all tasks have capital-labor ratios clustered within a very narrow band, g will have a huge spike there and be zero elsewhere. We will focus below on the former case, which we will call the 'high-variance' case, in which the response of $\bar{z}$ can be made arbitrarily close to zero. In equilibrium, any offshoring firm will have zero profits:

$$(1+\tau)\int_0^{\bar{z}} c^z(w,r)dz + \int_{\bar{z}}^1 c^z(w^*,r^*)dz = p^X, \tag{4}$$

and any firm that produces only in the US will also have zero profits:

$$\int_0^1 c^z(w,r)dz = p^X. \tag{5}$$

Firms that offshore will do the same number of units of each task in the US as in Mexico. This can be called the "production-matching" condition, and can be derived as follows. First, if n^{NO} units of each task are performed by non-offshoring firms, the capital used by non-offshoring firms will be $n^{NO}\int_0^1 c_2^z(w,r)$. The capital available to those firms will be equal to $K - K^O$, so:

$$\frac{K - K^O}{\int_0^1 c_2^z(w,r)} = n^{NO}, \tag{6}$$

and consequently the labor used by non-offshoring firms is equal to:

$$\left(K - K^O\right) \frac{\int_0^1 c_1^z(w,r)}{\int_0^1 c_2^z(w,r)}. \tag{7}$$

The difference between $E^X(w)$ and this expression must be the amount of US labor used by offshoring firms. Their labor use per unit of each task is given by $\int_0^{\bar{z}} c_1^z(w,r)$, so the number of units n^O of each task performed by offshoring firms is given by:

$$n^O = \frac{E^X(w) - \left(K - K^O\right) \frac{\int_0^1 c_1^z(w,r)dz}{\int_0^1 c_2^z(w,r)dz}}{\int_0^{\bar{z}} c_1^z(w,r)dz}. \tag{8}$$

In equilibrium, this must be equal to the number of tasks those same firms perform of each task in Mexico, and so we find the production-matching condition:

$$\frac{E^X(w) - \left(K - K^O\right) \frac{\int_0^1 c_1^z(w,r)dz}{\int_0^1 c_2^z(w,r)dz}}{\int_0^{\bar{z}} c_1^z(w,r)dz} = \frac{E^{X*}}{\int_{\bar{z}}^1 c_1^z(w^*,r^*)dz}. \tag{9}$$

In addition, we need labor-market-clearing conditions for both countries. For the US, the condition is:

$$\left(K - K^O\right) \frac{\int_0^1 c_1^z(w,r)dz}{\int_0^1 c_2^z(w,r)dz} + \left(K^O\right) \frac{\int_0^{\bar{z}} c_1^z(w,r)dz}{\int_0^{\bar{z}} c_2^z(w,r)dz} = E^X(w), \tag{10}$$

where the left-hand side denotes effective labor demanded by non-offshoring and offshoring X firms respectively, and the right-hand side denotes effective labor supply to the X industry. The corresponding condition for Mexico is:

$$(K^*) \frac{\int_{\bar{z}}^1 c_1^z(w^*,r^*)dz}{\int_{\bar{z}}^1 c_2^z(w^*,r^*)dz} = E^{X*}(w^*). \tag{11}$$

An equilibrium is a set of values for w, $w*$, r, $r*$, $\bar{z}$, and K^O that satisfy (2), (4), (5), (9), (10), and (11).

4.2.2 Partial Equilibrium.

To see how the equilibrium changes with a change in tariff it is helpful to break the system down into parts. Take w, w^* and K^O as given for the moment, and consider how r, r^*, and $\bar{z}$ must adjust to satisfy (2), (4), and (9). Call the resulting values $r(w,\ w^*, K^O; \tau)$, $r^*(w,$ $w^*, K^O; \tau)$, and $\bar{z}(w,\ w^*, K^O; \tau)$ respectively. To provide a simple example, we will focus on the Leontief case, in which $c^z(w, r)$ is linear in the factor prices.

Proposition 1. In the Leontief case, the partial-equilibrium comparative statics yield:

$r_1 < 0$, $r_2 > 0$, $r_3 < 0$ and $r_4 < 0$;

$r_1^* > 0$, $r_2^* < 0$, $r_3^* > 0$, and $r_4^* > 0$;

$\bar{z}_1 > 0$, $\bar{z}_2 < 0$, $\bar{z}_3 > 0$, and $\bar{z}_4 = 0$.

These relationships are reasonably easy to understand. For example, holding w^* and K^O constant, raising w will raise the labor supply to the X industry in the US, which by the production-matching condition (9) will increase the quantity of each task done in the US. This requires an increase in the number of tasks done in the US to restore production matching, which requires a rise in $\bar{z}$. From (2), this requires a rise in r^* or a fall in r, and to maintain zero profits (4) we must have both.

4.2.3 Full equilibrium.

Now we endogenize the wages, using the labor-market clearing conditions (10) and (11). For the moment we still hold K^O fixed, and do not impose the zero-profit condition (5) for non-offshoring firms. In analyzing these conditions, we treat r, r^*, and $\bar{z}$ as functions of w and w^* as in Proposition 1.

Consider (10). Suppose that initially it holds with equality. A rise in w then increases the right-hand side through the labor-supply response. In the Leontief case, the left-hand side can change only through a change in $\bar{z}$. Any increase in $\bar{z}$ will increase the left-hand side because the new tasks added to the US production mix will be more labor-intensive than the ones already included (the second ratio of integrals on the left-hand side is an increasing function of $\bar{z}$). From Proposition 1, an increase in w (with adjustment to r, r^*, and $\bar{z}$ to keep (2), (4), and (9) satisfied) will increase $\bar{z}$, thus causing the left-hand side of the equation to rise. If we assume the 'high-variance' case for labor intensivity among tasks, the change in $\bar{z}$ will be small enough that the right-hand side of the equation will be greater than the left-hand side. This means that w^* must adjust to raise the left-hand side to restore equality, which means that $\bar{z}$ must rise, which, again from Proposition 1, means that w^* must fall. In the limit as the variance of labor intensitivities becomes large, (10) will simply define a market-clearing level of w regardless of w^*.

Similarly, (11) defines a market-clearing value of w for each value of w^*, and in the limit with the high-variance case, it defines a market-clearing value of w^* regardless of w. The two conditions together determine w and w^*, given K^O. We can plot the two equations in a figure with w on the horizontal axis and w^* on the vertical axis, with the solution given by the intersection. In the high-variance case, the curve for (10) will be slightly downward-sloping, but almost vertical, and the curve corresponding to (11) will be slightly upward-sloping but almost horizontal. Now note that an increase in K^O will shift the US labor-market-clearing curve (10) to the left.[8] This leads to the following:

Proposition 2. In the Leontief case with high variance in labor intensities among tasks, a rise in the portion K^O of capital that is used for offshoring lowers the US X-industry wage, w.

Of course, K^O is an endogenous variable, and must take a value such that, once the effects on all factor prices have been taken into account, (5) will be satisfied.

Finally, consider the comparative-statics question that is our main interest: The effect of a drop in the tariff τ on the US wage. For the moment we hold K^O fixed. First, note that in the Leontief case, the only way (10) or (11) will be affected by the drop in the tariff

[8]The labor-intensivity assumption is important here. The ratio of integrals in the first term of the equation is greater than the ratio of integrals in the second term because the tasks beyond $\bar{z}$ are all more labor-intensive than the tasks before $\bar{z}$.

is through a change in $\bar{z}$, but by Proposition 1 a change in tariff will not affect $\bar{z}$, so the change in tariff will not change wages unless it causes a change in K^O. This will occur if the unit cost of a non-offshoring firm is changed. Note that throughout we are imposing zero-profits for the offshoring firms (through (4)), so if the unit cost rises for a non-offshoring firm, the result will be that firms would want to switch to offshoring, increasing K^O, and vice versa if the unit cost falls. Again from Proposition 1 a drop in τ will raise r, but we have just seen that w will be unchanged absent a change in K^O. Consequently, unit costs for non-offshoring firms rise, and K^O must rise. But as seen in Proposition 2, this will drive down w. Consequently we have:

Proposition 3. A drop in the tariff τ will increase K^O and thereby lower w.

This is the main result. A reduction in the Mexican tariff on industry X, other things equal, reduces costs for offshoring firms but not for firms that do not use offshoring. This causes an increased use of offshoring, which expands (increasing K^O) until the diminished demand for US labor that results lowers the US X-industry wage (lowering costs for non-offshoring firms more than offshoring firms) until firms are once again indifferent between the two modes of production.

Note that this is an outcome that will occur in part of the parameter space but not in all of the parameter space. In particular, we have shut down two important adjustment mechanisms that are likely to moderate any downward pressure on the US X-industry wage. First, by assuming Leontief production we prevent firms from substituting away from capital as the wage falls. Second, by focusing on the high-variance case in labor-intensities across tasks we prevent a substantial increase in the scope of tasks done domestically by an offshoring firm (the intensive-margin effect). What we have demonstrated is that it is entirely *possible* for a drop in Mexico's tariff to cause a drop in wage for US workers in the same industry, by encouraging an increase in offshoring.

4.3 A simple empirical test.

We test this hypothesis with an exercise similar in spirit to Ebenstein et al (2014). If indeed workers in industries whose Mexican tariffs fell had lower wage growth because those industries increased their offshoring to Mexico, then we should see the wage effect most strongly in those workers whose occupations are most easily offshorable. We use the Blinder (2009) measure of offshorability, based on task composition of each occupation as recorded in the O*NET data created for the US Department of Labor. Our data list the occupation as well as industry and location for each worker, so we can include the Blinder measure of offshorability of the worker's occupation in the regression equation along with all of the other variables. In addition, we interact offshorability with all of the tariff variables. In this way we can evaluate the question: Is the wage effect that we identified in our main regression stronger for workers in more offshorable occupations?

The offshorability measures in Blinder (2009) are listed by the Department of Labor's SOC occupation codes. The measure was adapted to Census occupation OCC1990 categories using a crosswalk. Whenever there were multiple SOC categories corresponding to a single OCC1990 category, an average offshorability level was created using employment shares as weights.

The results of this exercise are shown in Table 4. The structure is analogous to Table 2. The first column reproduces the results from Table 2 for comparison. The second column shows the estimated coefficients for the regression with interactions between offshorability and the industry tariff variables added. The coefficients on those interaction terms are displayed in the bottom four rows. Inclusion of these terms eliminates most of the effect of the industry tariff variables (rows 5 through 8), but the interaction terms are negative and strongly significant for high-school dropouts, and also – surprisingly – significant for college graduates. The interpretation is that for a worker in a non-offshorable occupation, the change in the Mexican tariff on that worker's industry makes no difference, but for a worker in a highly offshorable occupation (such as offshorability = 1, the maximum), the drop in

Table 4: Differences Between Initial-tariff and Impact Effects

	Baseline	Interaction with occupation offshorability	Interaction with occupation and local offshorability
	(1)	(2)	(3)
Mexican Tariff Measures			
Location Effect			
Less than high school	-1.906***	-1.881***	-1.887***
High school graduate	-1.237***	-1.233***	-1.24***
Some college education	-1.279***	-1.281***	-1.418***
College graduate	0.032	0.041	-0.128
Industry Effect			
Less than high school	-0.199***	-0.005	-0.007
High school graduate	-0.11***	-0.051	-0.054
Some college education	-0.096***	-0.096**	-0.1*
College graduate	-0.074	0.04	0.034
Interactions with Offshorability Index or Local Offshorability			
Location Effect			
Less than high school			0.029
High school graduate			0.028
Some college education			0.743
College graduate			0.962
Industry Effect			
Less than high school		-0.484***	-0.484**
High school graduate		-0.145	-0.148
Some college education		-0.004	-0.007
College graduate		-0.237*	-0.237

Notes: N=10,320,274. The table reports the overall impact on wages (computed as a difference between initial-tariff and impact effect) and its significance for each education group when a US location or industry gains duty free access to Mexican market between 1990 and 2000. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively. Agricultural tariffs are set to zero in all regressions.

the Mexican tariff on that worker's industry implies a drop in the worker's wage. This is consistent with the theory sketched above. The fact that the interaction with offshorability is significant for college-educated workers is telling; such workers on average show no wage effect from the tariff reductions, but that subset of the college-educated who are in offshorable occupations do.

The final column shows the results after controlling for a measure of the potential aggregate offshoring shock to the local economy. Define:

$$offshorable_c \equiv \frac{\sum_{i \in c} \left(blinder_i (\Delta RCA_{j(i)} \tau_{j(i)}) \right)}{n_c}, \tag{12}$$

where $blinder_i$ is the offshorability of worker i's occupation, $j(i)$ is worker i's industry, n_c is the number of workers in conspuma c, and the summation is over all workers in conspuma c. This variable measures the average interaction between the change in industry tariff (weighted by revealed comparative advantage) and the offshorability of occupation, for each worker in conspuma c. Note that if all occupations are maximally offshorable ($blinder_i \equiv 1$), then this measure is identical to the change in local average industry tariff in the baseline regression, while if no occupation is offshorable at all it will be equal to zero. The value of $offshorable_c$ will tend to be higher in local labor markets where the most important industries are experiencing a declining Mexican tariff and also have offshorable workers than in a labor market where the industries losing their tariffs and the industries with offshorable workers are different. This is thus a measure of the aggregate labor-demand shock due to the offshoring channel. Controlling for this effect changes almost nothing in the previous coefficients. The only change worth mentioning is that the interaction with industry offshorability for college-educated workers is no longer significant. In particular, the interaction with offshorability for high-school dropouts remains strongly negative. The local offshorability shocks themselves do not appear to have any effect on wages.

These results provides some support for the hypothesis that the paradoxical effect of

Mexican tariff reductions noted at the outset is caused at least partly by increased offshoring made possible by those tariff reductions, at the industry level, but not at the level of the local labor market.

5 Conclusion

In previous work, we looked at the effect of US tariff reductions under NAFTA on US labor market outcomes, and found that blue-collar workers in industries and locations that lost tariff protection experienced slower wage growth compared to other workers. Here, we examine the corresponding reductions in Mexican tariffs on imports from the US. Surprisingly, we find that blue-collar workers in industries or locations whose Mexico tariffs fell also experienced slower wage growth compared to other workers. We tentatively suggest that the most plausible explanation for this finding is that the tariff reductions made it easier for US manufacturers to use offshoring to Mexico to lower costs.

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