

## Environmental injustice along the US–Mexico border: residential proximity to industrial parks in Tijuana, Mexico

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2015 Environ. Res. Lett. 10 095012

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## Environmental Research Letters



## LETTER

## Environmental injustice along the US–Mexico border: residential proximity to industrial parks in Tijuana, Mexico

## OPEN ACCESS

## RECEIVED

29 May 2015

## REVISED

5 August 2015

## ACCEPTED FOR PUBLICATION

2 September 2015

## PUBLISHED

22 September 2015

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Keywords: Tijuana, Mexico, environmental justice, maquiladoras, social inequality

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**Abstract**

Research in the Global North (e.g., US, Europe) has revealed robust patterns of environmental injustice whereby low income and minority residents face exposure to industrial hazards in their neighborhoods. A small body of research suggests that patterns of environmental injustice may diverge between the Global North and South due to differing urban development trajectories. This study uses quantitative environmental justice methods to examine spatial relationships between residential socio-demographics and industrial parks in Tijuana, Baja California Norte, Mexico using 2010 census data for Tijuana's 401 neighborhoods and municipality-provided locations of industrial parks in the city. Results of spatial lag regression models reveal that formal development is significantly associated with industrial park density, and it accounts for the significant effect of higher socioeconomic status (measured using mean education) on greater industrial density. Higher proportions of female-headed households are also significantly associated with industrial park density, while higher proportions of children and recent migrants are not. The formal development findings align with other studies in Mexico and point to the importance of urban development trajectories in shaping patterns of environmental injustice. The risks for female-headed households are novel in the Mexican context. One potential explanation is that women factory workers live near their places of employment. A second, albeit counterintuitive explanation, is the relative economic advantage experienced by female-headed households in Mexico.

**1. Introduction**

The majority of environmental justice (EJ) studies over the past several decades have examined US cities. In the US, the majority of studies have found that poor and racial/ethnic-minority people are disproportionately impacted by technological hazards (Mohai *et al* 2009, Jones *et al* 2014, Zou *et al* 2014). A growing body of literature examines environmental injustices in other countries of the Global North, e.g. Canada (Dale *et al* 2015), Australia (Chakraborty and Green 2014), France (Laurian and Funderburg 2014), Italy (Germani *et al* 2014) and Portugal (Nogueira *et al* 2013), where findings generally are similar to the US.

There is a small and growing quantitative EJ literature related to the Global South that suggests different

patterns of injustice. For example, in Bangalore (India), workers with higher incomes faced greater personal exposure to traffic-related air pollution because longer commuting times offset the benefits of lower ambient concentrations, as compared to lower income workers (Sabapathy *et al* 2015). In Mexico, several studies have examined patterns of environmental injustice in Ciudad Juárez (Blackman 2004, Grineski and Collins 2008, Grineski and Collins 2010, Grineski *et al* 2010, Grineski *et al* 2012, Grineski *et al* 2015). The studies have found that it is generally economically better-off residents who are exposed to greater densities of industrial hazards (Grineski and Collins 2010), which is the opposite of what is usually found in the Global North. This has been posited to relate to urban development trajectories that are

fundamentally different in the Global South, where elites are more likely to inhabit the urban core where they can take advantage of its paved roads and relatively developed civil infrastructure, among other benefits, while the most socially marginalized reside in informally developed peri-urban areas. However, when an indicator of formal development (an atypical EJ variable in the North) was analyzed alongside social class in Juárez, the relationship flipped and it was highly developed neighborhoods and those of lower social class that were found to face the greatest risk (Grineski and Collins 2008).

To our knowledge, there has been only one previous quantitative EJ study of Tijuana, Mexico (Kopinak and Barajas 2002), the location of this analysis. Using 1998 data, results suggested that factories (i.e., *maquiladoras*) were located in more densely populated areas with higher concentrations of children. Unfortunately, the authors relied on qualitative inspection of maps, as opposed to statistical analysis of the spatial data (Kopinak and Barajas 2002). Researchers also surveyed nearly 800 *maquiladora* workers and found that the newest workers (usually migrants from other parts of Mexico) lived closer to the plants than did more senior workers and were thus exposed to greater risks (Kopinak and Barajas 2002).

With this analysis, we build on this 1998 study by examining current conditions using 2010 census data and employing advanced spatial statistical methods (i.e., spatial autoregressive models). We contribute to a growing literature on EJ in Mexico that has been almost entirely concentrated in Juárez (see Lara-Valencia et al 2009 for an exception). This analysis allows us to compare patterns of distributional injustice between Juárez and Tijuana and explore if the posited explanations for patterns of environmental injustice in Juárez (Grineski and Collins 2008, Grineski and Collins 2010, Grineski et al 2010) also apply to Tijuana.

### 1.1. Tijuana and its *maquiladoras*

Tijuana, Mexico is the largest city in Baja California Norte and the 5th largest city in Mexico. Its population in 2010 was 1 300 983. Tijuana shares a 24 km boundary with San Diego, California (its US sister city). It is a dominant manufacturing center in the Americas and is home to many multinational *maquiladoras* (assembly plants that produce items for export). Tijuana has more *maquiladoras* than any other city in Mexico and is second only to Ciudad Juárez in terms of the number of people employed in them (Kopiak 2012).

The *maquiladora* phenomenon traces its roots to the Bracero Program, started by the US government in 1942. This program legalized the migration of Mexican workers into the US to replace those serving in World War II. When the program ended in 1964, several hundred thousand Mexican workers were returned to Mexican border cities. In an attempt to alleviate

overcrowding and unemployment in these cities, the Mexican government created the Border Industrialization Program to promote industrial development and employment (Liverman and Vilas 2006).

As a result, the *maquiladora* industry grew tremendously during the 1970s. In 1970, Mexico had 72 factories, and by 1979, it had 620. Today, there are approximately 3000 *maquiladoras* in Mexico's northern border region (defined as the zone stretching 60 km inward from the international boundary). These mostly US-owned transnational corporations import needed equipment and raw materials tax free. The passage of the North American Free Trade Agreement (NAFTA) in 1994 enabled continued growth in the *maquiladora* sector along the Mexican side of the border because it reduced tariff barriers to trade (Frey 2003). Some have argued that growth in the *maquiladora* sector post-NAFTA has added to environmental degradation and health risks in the region (Williams and Homedes 2001). Evidence to support this includes violations of environmental laws by foreign-owned companies made possible through poor enforcement, a lack of adequate environmental legislation, and a weak institutional framework in Mexico (Cooney 2001, Roberts and Thanos 2003). Others have shown that foreign-owned *maquiladoras* are actually cleaner and more responsive to environmental regulations than are locally owned industries (Contreras et al 2006, Liverman and Vilas 2006). While there is a debate as to the extent that *maquiladoras* damage the environment, there is consensus that the overall growth of industrial activity along the border has caused environmental degradation and amplified health risks (Schatan and Castilleja 2005, Liverman and Vilas 2006).

Nonetheless, little known about the specific environmental health effects of *maquiladoras* (Kopiak 2012), especially on proximate residents. Some health statistics in Baja California (and other border states) are worse than rest of Mexico (e.g., higher age-adjusted mortality, infant mortality, and perinatal mortality) (Harlow Denman and Cedillo 2004). A study of children living in six Mexican cities determined that children with the highest levels of flame retardants (i.e., polybrominated diphenyl ethers) in their blood serum resided in an urban and industrial area, as compared to the children living in a rural area, near a landfill, or in an urban but not industrial area (Pérez-Maldonado et al 2009). This suggests that residence near industrial land uses in Mexico is a health risk for proximate residents.

Several older studies have documented that *maquiladoras* create air, soil and water pollution through their activities. They generate toxic chemical wastes (e.g., solvents, acids, and heavy metals), which are sometimes spilled or improperly disposed of (Sanchez 1990). For example, toxic effluents in drainage ditches flowing from *maquiladoras* into neighboring communities have been documented to contain

contaminants (e.g., chromium, lead) in excess of US Environmental Protection Agency standards (Williams and Homedes 2001). Electronics *maquiladoras*, which are a growing sector, pose a serious threat to human health and the environment because of the acids, hydrocarbon solvents, organochlorides, and heavy metals that they use (Sanchez 1987, Quintero and Romo 2001). The *maquiladoras* also have the potential to be sites for acute industrial accidents, such as the 2013 explosion at a Juárez *maquila* that killed eight and injured many others.

A recent series of studies has focused on air quality in Tijuana through the Cal-Mex 2010 field monitoring campaign (Bei *et al* 2013, Shores *et al* 2013, Minguillon *et al* 2014) and the results revealed serious air quality concerns in the region. For example, environmental monitoring near Parque Morelos (a municipal park in central Tijuana) for black carbon, a pollutant with known respiratory and cardiovascular effects, revealed sharp, extremely high, and regularly occurring peaks around midnight. These peaks were comparable to occupational exposure in workplaces dominated by diesel exhaust exposure and the authors believe they were caused by clandestine industrial activity. Overall, in Tijuana, black carbon levels were two times higher than in San Diego (Shores *et al* 2013).

A lack of government oversight of the *maquiladora* sector is endemic, which likely contributes to an environmental crisis of unknown magnitude. A Tijuana environmental activist with the Environmental Health Coalition reported, 'government oversight is poor. There are not enough inspectors. There is no obligatory inspection scheme, only a voluntary one, and inspections are arranged in advance, with no surprise visits. We have seen gradual deterioration in the urban communities where the factories are located' (Godoy 2011). Her perspective has been echoed by a study of environmental regulations in Mexican *maquiladoras* (Schatan and Castilleja 2005). For example, results of a Profepa (*la Procuraduría Federal de Protección al Ambiente* or the Office of the Federal Attorney for Environmental Protection) inspection of *maquiladoras* in Mexico in 2002 showed that only 38% of the plants were in full compliance with environmental standards and the trend is toward increasingly fewer inspections.

The lack of compliance with standards should not come as a surprise when one considers the institutional and technical capabilities for inspection and enforcement in the region. There are many challenges that make environmental enforcement difficult. These include strong interests preventing enforcement; vague and weak regulations; underpaid enforcement agents that are easily bribed; a lack of clarity regarding responsibility for environmental enforcement; municipalities' lack of monitoring equipment; lack of technical knowledge among staff, and excessive work demands on staff (Montalvo Corral 2004).

At the level of the factory, additional regulatory challenges exist (Schatan and Castilleja 2005). Only 54% of the 200 plants that Schatan and Castilleja (2005) surveyed in Tijuana, Juárez and Mexicali had an active environmental policy and 63% possessed an environmental unit or were under environmental auditing. This is in spite of the fact that 89% were foreign-owned and many parent companies have significant environmental protection measures in place at their domestic facilities. While over half had some form of environmental protection policies in place, they spent a very small percentage of their operating costs on this aspect of production. Very little training was provided on environmental issues. For example, out of the 190 plants that provided training to their engineers and technicians, only three had done so in relation to environmental standards (Schatan and Castilleja 2005). Additionally, the factories have the power to quell community resistance to their operations at the local level due to the steady supply of labor available along the border, close relationships with municipal authorities, and the vast economic resources of their transnational parent companies, which far outweigh local resources and can be marshaled toward halting mobilizations (Morales *et al* 2012). Taken together, this evidence suggests that the assumption we make in this paper that there are risks associated with living near industrial parks in Tijuana is tenable.

## 2. Methods

### 2.1. Data

In this paper, we use *áreas geoestadísticas básicas* (AGEBs) to operationalize neighborhoods, which are similar in size and population to US census block groups. We analyzed only AGEBs with more than 500 residents. This meant that 33 AGEBs were excluded for a total  $N$  of 410.

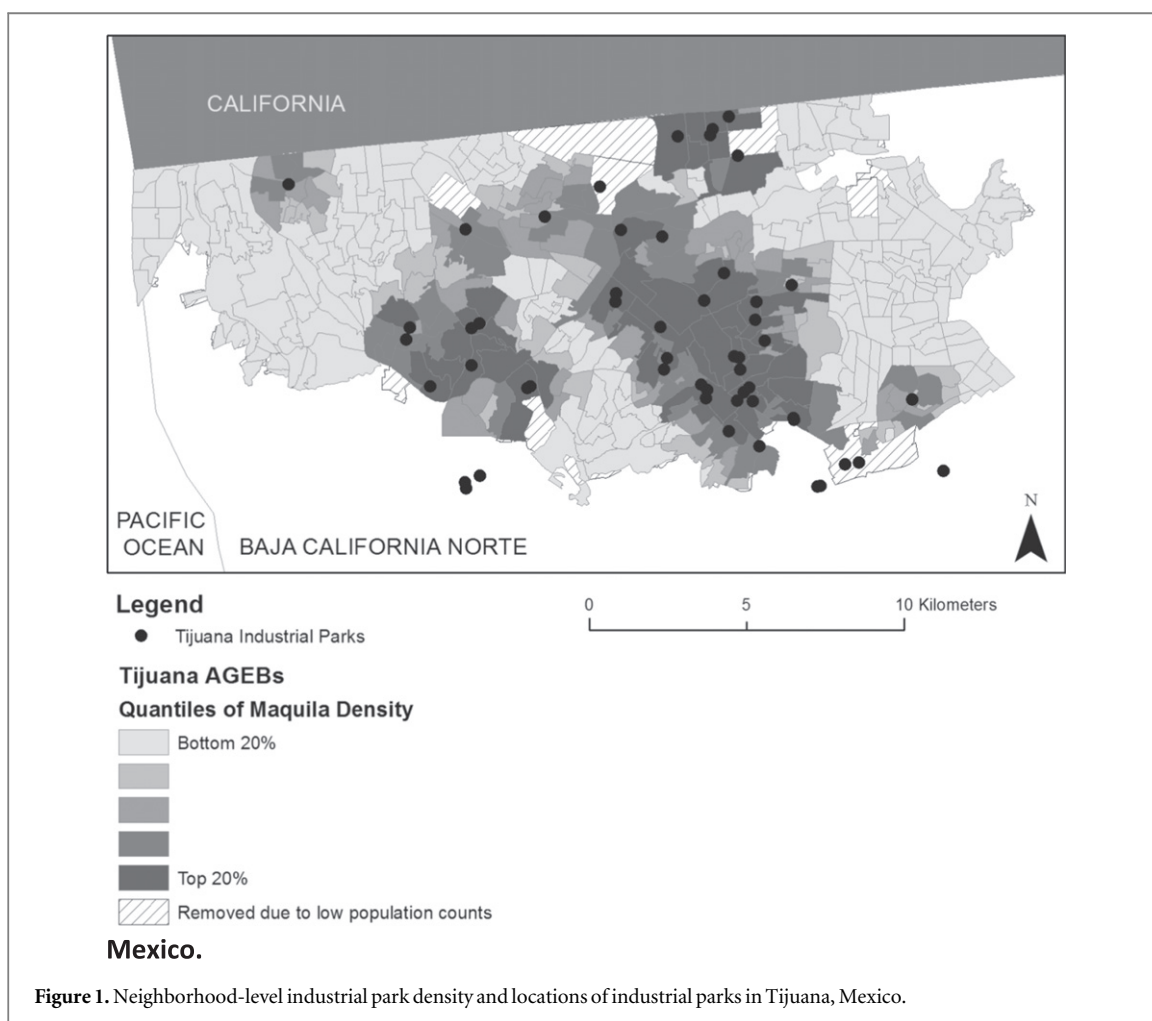
#### 2.1.1. Dependent variable: industrial park density

The study relies on the locations of the industrial parks, which are home to *maquiladoras*, in Tijuana. We acquired spatial locations of industrial parks in Tijuana from the *Instituto Municipal de Planeación de Tijuana* (IMPLAN). The information was current as of 2005, which is the most recent data available. Contacts at IMPLAN stated that while the dataset may be missing some newer, smaller industrial parks, all current major industrial parks are included in this file.

We used the hazard density index method of representing hazard (Bolin *et al* 2002), which gives each neighborhood a hazard score based on the density of industrial parks in the neighborhood. To create the scores using this method, we used ArcGIS 10 software. We began the process by drawing a 1 km buffer around each industrial park. Because we do not know the quantity and toxicity of emissions for the factories

**Table 1.** Descriptive statistics of analysis variables: Tijuana (2010),  $N = 410$ .

	Min.	Max.	Mean	Stan. Dev.
Proportion recent migrant	0.010	0.19	0.06	0.026
Mean education	6.74	14.49	9.43	1.64
Proportion population that < age 12	0.05	0.35	0.23	0.046
Proportion female-headed household	0.13	0.49	0.27	0.056
Industrial park hazard density index (ln)	-9.21	1.94	-5.54	4.16
Formal development factor	-12.00	1.16	0.00	1.00
Proportion no dirt floor	0.54	1.00	0.96	0.048
Proportion electric lights	0.67	1.00	0.99	0.020
Proportion piped water	0.03	1.00	0.96	0.101
Proportion sewage infrastructure	0.65	1.00	0.98	0.046
Proportion refrigerator	0.50	1.00	0.93	0.050
Proportion washing machine	0.24	0.98	0.78	0.096



in each park, we have assumed—based on our choice of buffer—that people living within 1 km of each industrial park are at risk. This buffer size is a more conservative estimate of the at-risk population than is a larger buffer, such as one-mile, although we acknowledge the important limitations of imposing such a boundary on exposure to risk (Mohai and Saha 2006). We then intersected the buffers and census geography boundaries (i.e., AGEBs) and calculated the area of each portion of the intersected buffers. We then summed the areas of all portions of buffers falling

within each AGEB unit. Lastly, that score was divided by the area of each spatial unit to create a unique hazard density score for each AGEB unit. We did not weight the hazard buffers by emissions (as is sometimes done in studies using US toxic release inventory data) because emissions data for the industrial parks (or the individual factories within the parks) are not collected by Mexican environmental authorities. In the analysis, we use the natural log of the industrial park density measure, since it reduced the skewness and kurtosis to acceptable levels. Descriptive statistics

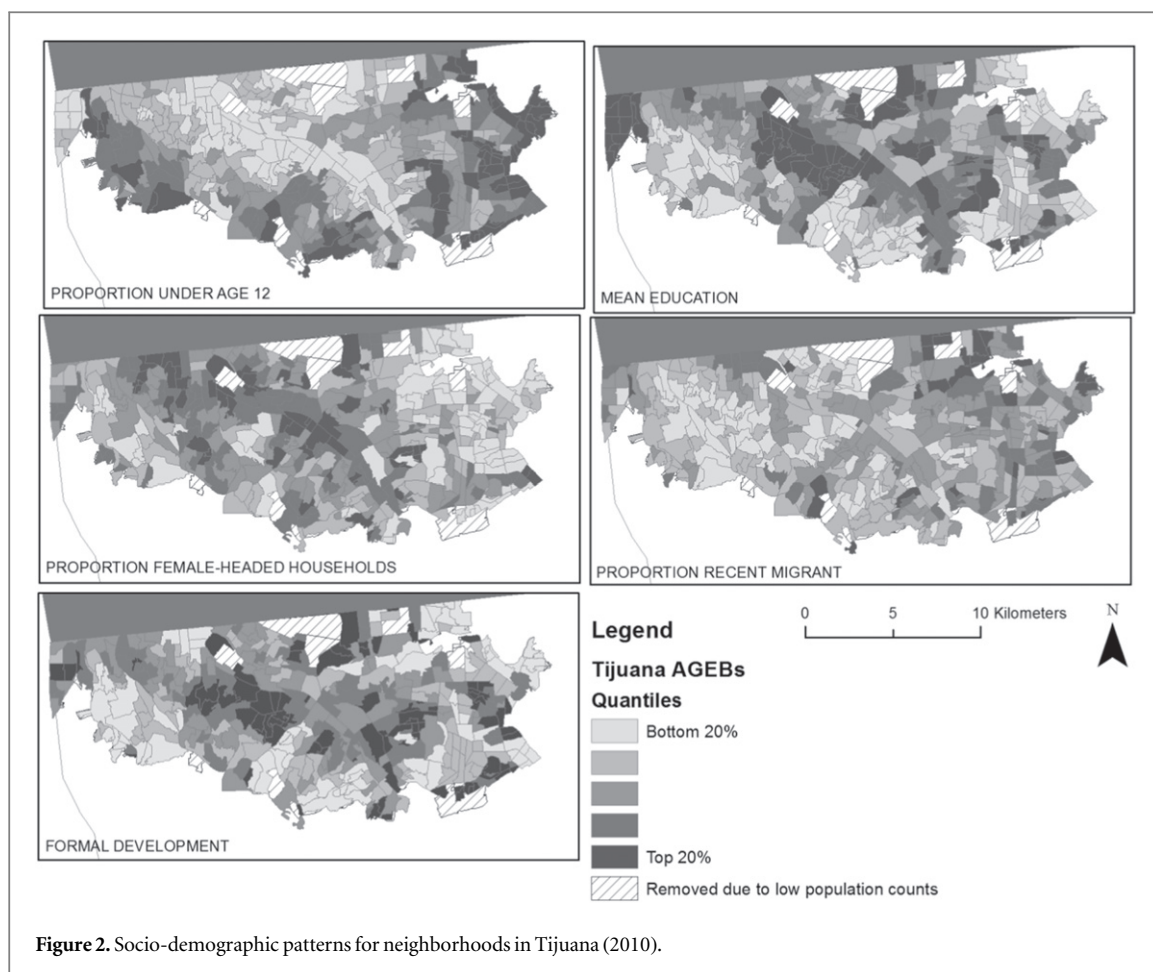


Figure 2. Socio-demographic patterns for neighborhoods in Tijuana (2010).

are included in table 1 and the variable is mapped in figure 1.

### 2.1.2. Independent variables

We use independent variables (see table 1 and figure 2) that have been used previously in similar studies of Juárez, Mexico. While previous studies in Juárez used a socioeconomic status factor that included mean education and employed persons making above the minimum wage, the minimum wage question was not asked on the 2010 Mexican census. For that reason, we use only mean education (*grado promedio de escolaridad*) as our socioeconomic status variable, which has been used similarly in previous studies in Mexico (Grineski and Collins 2010, McDonald and Grineski 2012). Specifically, the mean is calculated for residents aged 15 and older.

Second, we include an indicator for the presence of children because previous studies (e.g., Downey and Hawkins 2008), including one in Juárez (Grineski and Collins 2008), have found an association between higher percentages of children and greater industrial hazard risks. The proportion children variable was calculated by dividing the number of children under 12 years of age in each neighborhood by the total population in each neighborhood.

Third, we consider the relationship between the proportion of migrants in a neighborhood and

industrial park density. The proportion migrant variable (*población de 5 años y más residente en otra entidad federativa en junio de 2005*) is defined as the proportion of neighborhood residents not residing in Tijuana in June of 2005. This variable is important as Tijuana, like Juárez, is a city that attracts many migrants from within Mexico due to employment opportunities in transnational sector, including *maquiladoras*.

Fourth, we use percent of households that are female-headed (*hogares censales con jefatura femenina*). Unlike in the US Census or American Community Survey, this variable does not specify whether a woman has children or not. While it was not a significant predictor of *maquiladora* density in Juárez (Grineski and Collins 2010), strong associations have been observed in the US (Downey and Hawkins 2008), so we included it here.

Finally, we considered an indicator of formal development, based on a similar factor created for Juárez (Grineski and Collins 2008). To create this variable, we ran a principal components analysis on six indicators of formal development: the proportions of occupied housing units with no dirt floors, electric lights, piped water, sewage infrastructure, refrigerator, and washing machine (*vivendas particulares habitadas con piso de material diferente de tierra, que disponen de luz eléctrica, que disponen de agua entubada en ámbito de la vivienda, que disponen drenaje; que disponen de*

*refrigerador; que disponen de lavadora*). The six variables loaded on the factor well as the loadings ranged from 0.654 to 0.885, and the Cronbach's alpha was 0.796. Descriptive statistics for the individual components are included in table 1.

## 2.2. Analysis methods

We begin by presenting correlations between all variables. Then, we present the results of two spatial regression models. The first model uses proportion under age 12, proportion female-headed households, mean education and proportion recent migrant to predict industrial park density in Tijuana. Formal development is added as another independent variable in the second model. The models were calculated using the open source software GeoDa (available at <http://geodacenter.asu.edu/>) following Chakraborty (2009). To begin model specification, we ran two ordinary least squares (OLS) regression models. We then tested residuals for spatial autocorrelation using the Univariate Moran's I test. Spatial autocorrelation 'refers to the tendency of variables to be influenced by their neighbors, a fact that will cause the errors in the regression analysis to not satisfy the independence conditions generally associated with OLS regression' (Pastor *et al* 2005: 134). Both models exhibited spatial autocorrelation in the residuals (at a  $p$ -value of 0.001) indicating that the data did not meet the assumptions of OLS regression models. The Lagrange Multiplier (LM) diagnostic test was used to suggest if a spatial lag or spatial error model would fit best for each model (Anselin 2005). Spatial lag models assume that spatial autocorrelation is present in the dependent variable, while spatial error models assume that the independent variables exhibit spatial dependence. In our case, the LM series suggested that the spatial lag specification was best for both models. A third diagnostic offered by GeoDa is the multicollinearity condition index. The condition index measures the stability of the regression results due to multicollinearity (Anselin 2005, Chakraborty 2009). Anselin (2005) suggests that a condition index of 30 is indicative of serious collinearity problems. The condition index score was 2.55 in Model 1 and 3.15 in Model 2, indicating that multicollinearity was unproblematic in either model.

Spatial econometric models are supported by means of the maximum likelihood method and they require sparse spatial weights (Anselin Syabri and Kho 2006), which are calculated based on a set of neighbor relationships (Pastor *et al* 2005). EJ researchers usually use the distance-based approach (based on the distance between centroids of the polygons) to define weights due to irregularly shaped census geographies (Chakraborty 2009). We began the model specification phase at 750 m and this band effectively removed the spatial autocorrelation; at this distance, only 43 AGEBS were without neighbors which is well within acceptable limits.

## 3. Results

Results of the correlations are presented in table 2. Lower proportions of children and higher proportions of female-headed households are associated ( $p < 0.01$ ) with greater industrial park density. Higher education and greater levels of formal development are also associated ( $p < 0.01$ ) with greater density of industrial parks. In terms of the relationships between the independent variables, higher proportions of children are associated ( $p < 0.01$ ) with higher proportions of migrants, lower proportions of female-headed households, lower mean education and less formal development. Higher proportions of migrants are associated ( $p < 0.01$ ) with lower proportions of female headed households and less formal development. Higher levels of mean education are associated ( $p < 0.01$ ) with higher proportions of female headed households and greater levels of development. Higher proportions of female headed households were associated ( $p < 0.01$ ) with greater levels of formal development.

Table 3 presents results from the spatial autoregressive models. Two findings are statistically significant at the  $p < 0.01$  level in the first model. Neighborhoods with better educated residents and higher proportions of female-headed households had higher levels of industrial park density.

We added formal development in the second model. This term was positive and significant, suggesting that more formally developed neighborhoods have greater hazard density. Female-headed households remained significant and positive. Education lost significance, although retained its positive association. Proportion children became nearly significant in the second model ( $p < 0.10$ ), and was negative, meaning that neighborhoods with lower proportions of children had greater hazard density.

## 4. Discussion

To summarize, we found that formal development was associated with industrial park density, and it accounted for the significant effect of higher mean education on greater density from the first model. Taken together, this demonstrates that the industrial parks are located in formally developed parts of the city, where better educated (higher social class) residents live. It must be noted that these more affluent residents living within the one kilometer buffers may not be as vulnerable to the impacts of these industrial hazards as poorer residents living near, but outside the zone of risk. Vulnerability is produced based on unequal exposure to risk and unequal access to resources (Wisner *et al* 2004). While social protections (e.g., assistance from the government) may be less available in the Mexican context as compared to the US, more affluent Tijuana residents are likely better

**Table 2.** Correlations between analysis variables: Tijuana, 2010,  $N = 410$ .

		Industrial park density (ln)	Proportion < age 12	Prop. migrant	Education	Prop. female-headed household	Formal development
Industrial park density (ln)	Corr.	1	-0.306**	-0.043	0.248**	0.292**	0.237**
Proportion < age 12	Corr.	-0.306**	1	0.353**	-0.421**	-0.625**	-0.310**
Prop. migrant	Corr.	-0.043	0.353**	1	-0.009	-0.357**	-0.289**
Education	Corr.	0.248**	-0.421**	-0.009	1	0.165**	0.599**
Prop. female-headed household	Corr.	0.292**	-0.625**	-0.357**	0.165**	1	0.256**
Formal development	Corr.	0.237**	-0.310**	-0.289**	0.599**	0.256**	1

Note: \*\* Correlation is significant at the 0.01 level (2-tailed).



**Table 3.** Results from spatial autoregressive models predicting industrial park hazard density.

Model details	Model 1				Model 2			
	Spatial lag (750 m) $R$ -squared: 0.590 Moran's $I = -0.098$				Spatial lag (750 m) $R$ -squared: 0.596 Moran's $I = -0.088$			
Model results								
Variable	Coefficient	Std.error	$z$ -value	$P$	Coefficient	Std.error	$z$ -value	$P$
Constant	-2.454	0.212	-11.561	0.000	-2.459	0.211	-11.672	0.000
Education	0.413	0.149	2.775	0.006	0.151	0.186	0.814	0.415
Proportion female-headed household	0.461	0.173	2.672	0.008	0.404	0.173	2.331	0.020
Prop. migrant	0.105	0.145	0.729	0.466	0.223	0.152	1.467	0.143
Prop. < age 12	-0.259	0.192	-1.347	0.178	-0.319	0.192	-1.660	0.097
Formal development					0.413	0.177	2.335	0.020
$Rho$	0.602	0.031	19.546	0.000	0.601	0.031	19.528	0.000

Note: All independent variables were standardized before being entered into the regression models.

able to engage in self-protective actions, which reduce their vulnerability. These actions include owning a car to facilitate rapid evacuation during an industrial accident, owning an air conditioner so that windows can be closed on 'bad air' days, and being able to seek high-quality health care for respiratory ailments. Additionally, female-headed households are a risk group for exposure to residential industrial hazards, as the variable was significant in both models. Models reveal that children and recent migrants were not at disproportionate risk for residential industrial exposure in Tijuana.

In terms of how the findings compare to Juárez, the other large, industrialized Mexican border city that has been studied extensively, the associations between formal development and industrial density are strong in both cities (Grineski and Collins 2008, Grineski *et al* 2010). The same is true for the association between higher class and higher industrial hazard density, when development is not considered (Grineski and Collins 2010). A basic relationship between higher class and hazardous waste generating facilities was also found in Nogales, Sonora (Lara-Valencia *et al* 2009).

Taken together, these studies support explanations forwarded in previous work (Grineski and Collins 2008, Grineski *et al* 2010). In Mexico and much of the Global South, urbanization is occurring at a rapid rate and it is driven, at least in part, by the international division of labor (DeOliveira and Roberts 1996). Within Global South cities the poor often reside in informal settlements in the low-rise peripheries (Davis 2006). The affluent tend to dwell in formal, centralized neighborhoods with access to basic infrastructure (e.g., piped water, sewage treatment, paved roads, and electricity). *Maquiladora* operators, with their Global North capital, can afford to pay the local premium for land that is served by the civil infrastructure needed for operations. *Maquiladoras* demand electricity, paved roads and a reliable water supply and thus co-locate with residential developments catering to more affluent people who also demand these services (Grineski *et al* 2010). While the

Latin American elites may consider the option of settling in the less-polluted urban fringes like their US counterparts, flight to the suburbs has not generally occurred because of insufficient investment in infrastructure and the high density of squatters in these areas, which impose costs and diminish exclusivity (DeOliveira and Roberts 1996).

Apart from that finding, patterns of environmental injustice in Tijuana diverged from Juárez. In Juárez, children (Grineski and Collins 2008, 2010) and recent migrants (Grineski *et al* 2010) were most at risk to industrial hazards near their homes. Female-headed households were not significantly at risk in Juárez, however, the regression coefficient was positive ( $p < 0.2$ ) (Grineski and Collins 2010). In Tijuana, it was neighborhoods with more female-headed households facing disproportionate risk, not neighborhoods with more children or recent migrants. US-based readers may find this surprising, since female-headed households face disproportionate environmental risks (Downey 2005, Downey and Hawkins 2008) and are among the most economically disadvantaged groups in that country (Villarreal and Shin 2008). In Tijuana, we found a positive correlation between higher mean education and higher proportion of female-headed households and a negative correlation between higher proportions of children and lower proportions of female-headed households, which is opposite the pattern commonly observed in the US where female-headed households tend to reside in poverty and have children. However, nationally in Mexico, female-headed households (with and without children) have similar and higher per capita incomes than men and are no more likely to be living in poverty than are male-headed households (Villarreal and Shin 2008). This may be because very poor women are more likely than affluent women to remain in unhappy marriages or to be incorporated into households headed by their parents or another relative than to head their own household (Villarreal and Shin 2008). Their enhanced economic circumstances may enable female-headed households to live in the more desirable, formally

developed areas of Tijuana and face risks from industrial hazards.

Female *maquiladora* workers choosing to live near their places of employment may also contribute to the increased risk for neighborhoods with greater proportions of female-headed households. A survey of 767 *maquiladora* workers in Tijuana revealed that 20 percent of workers lived in the same neighborhood or a neighborhood adjacent to the factory where they worked (Kopinak and Barajas 2002). Those respondents who were more likely to live near their place of employment were recent migrants to Tijuana (versus those born in Tijuana) and female-headed households (versus male-headed households) (Kopinak and Barajas 2002). In total, half of the women workers surveyed lived within the same *delegación* (i.e., borough) as their factory, which could be contributing to this finding.

#### 4.1. Limitations

The study suffers from data limitations that are characteristic of quantitative EJ work in the Global South. While income is a commonly employed variable in EJ studies, we could not use it here because Mexico did not collect this information in their 2010 census. We have assumed—based on our choice of buffer—that people living within 1 km of an industrial park are at risk and that those living beyond one-kilometer face no risk. There are issues with imposing static boundaries on risk which have been discussed elsewhere (Downey 2005, Mohai and Saha 2006). While there are health risks associated with proximity to industrial hazards, we do not know the exact spatial dimensions of risk for each park. Risks would vary between chronic air pollution risks and risks from industrial accidents, and based on emissions at each park. But data needed to characterize these differences were not available. Our choice of a static buffer also neglects the temporality of risk; some factories release more emissions at night than they do during the day. Our method also neglects workplace hazards faced by employees (Abell 1999) and those put at risk (e.g., border crossers, people living along transportation routes) by the movement of hazardous materials imported, produced and exported as a result of industrial production processes (Good Neighbor Environmental Board 2007).

## 5. Conclusion

Our results for Tijuana generally align with the trends observed in Juárez and Nogales whereby developed, more affluent zones of each city face disproportionate risk from industrial hazards (Grineski and Collins 2008, Lara-Valencia et al 2009). Analyses employing a similar suite of variables should be conducted in other cities in Latin America and the Global South, apart from those in Mexico, to further efforts to better

understand meta-linkages between social marginality and the hazardousness of place. While the poor are not at disproportionate risk from residential exposure to industrial parks in Tijuana, it is important to underscore that they likely face threats from other types of hazards. Lacking social protections more often available in the Global North (e.g., property insurance, well-funded emergency response systems), residents of peri-urban areas in the South are often at great risk to natural hazards (like flooding) and illegal/informal polluting industries (Davis 2006). Lastly, the finding that disproportionate risks are experienced within Tijuana neighborhoods containing higher proportions of female-headed households is novel in the Mexican context and should be cause for concern. Future studies, including those using qualitative methods, should explore reasons behind these women's heightened exposure to industrial park risks and in the case of *maquiladora* workers, the synergy between workplace and residential risks.

## Acknowledgments

This work was supported by the Southwest Consortium for Environmental Research and Policy (SCERP) Environmental Protection Agency (EPA) Cooperative Agreement EM 83486101-01.

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