Immigration and Environment in the U.S.: A Spatial Study of Air Quality

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1. Introduction

The United States has long ranked as the top destination country for international migrants. According to the United Nations, the immigrant population in the U.S. reached 49.8 million in 2017, accounting for 19 percent of the world's total (UN, 2017: 6). Despite the importance of immigration in U.S. history and society, issues of immigration are politically charged and hotly debated, with many political leaders and activists calling for increased restrictions on immigration. Environmental issues, like immigration issues, have gained much attention academically and politically. While opponents cite many reasons to halt immigration, the environmental threat posed by immigrants is an issue that uniquely bridges disparate parts of the American political spectrum (Hultgren, 2014; Park & Pellow, 2011).

Immigrants have been blamed for environmental problems such as air pollution and energy shortages (Beck, 1996; Beck, Kolankiewicz, & Camarota, 2003; Cafaro & Staples, 2009; Cafaro, 2015; Chapman, 2006; DinAlt, 1997; Garling, 1998; Krikorian, 2008; Population-Environment Balance, Inc. 1992; Simcox, 1992; Zuckerman, 1999). Others argue that this claim ignores the root causes of both immigration and environmental issues (Angus & Butler, 2011; Hultgren, 2014; Muradian, 2006; Neumayer, 2006). Moreover, research indicates that immigrants consume less and produce less waste than natives (Atiles & Bohon, 2003; Bohon, Stamps, & Atiles, 2008; Blumenberg & Shiki, 2008; Chatman & Klein, 2009; Hunter, 2000; Pfeffer & Stycos, 2002).

Because immigration is a substantial factor in U.S. population growth, immigration has a clear potential for impact on environmental quality through population pressure, as any type of population growth would. But the argument that population pressure is detrimental to the environment is not sufficient to prove that immigration specifically is harmful. There is a stark contrast between the widespread claims of negative environmental impacts of immigration and the scanty empirical research on this issue. To the best of our knowledge, there are only five empirical studies on the association between environment and immigration in the U.S. (Cramer, 1998; Price & Feldmeyer, 2012; Squalli, 2009, 2010; Authors, n.d.). The five studies analyze the association between immigration and air quality with variation in their indicators of air quality, study units, and methods. All found little or no relationship between immigration and most indicators of air pollution. These studies provide valuable evidence for the debate over the relationship. However, only one considers spatial dependence, which is an important feature of air quality, and all are hampered by limited sample sizes.

Spatial analysis has been widely used to reduce estimation bias caused by spatial effects. This study aims to examine the association between air quality and immigration by using spatial analysis to account for spatial autocorrelation of air quality. We utilize the Environmental Quality Index (EQI), which was constructed by the Environmental Protection Agency (EPA) during 2000-2005 for all the U.S. continental counties (the only air quality index available across all U.S. counties), and variables from population, economic development, to location characteristics. Our spatial model provides insights into the relationship between air quality and immigration across all contiguous U.S. counties.

2. Literature review

The population pressure perspective links immigration to environmental degradation in the U.S. through the impact of immigration as a component of population growth. We present a review of this body of work, followed by a review of the much smaller body of research on the specific association between immigration and environment.

2.1 Population pressure perspective and immigration

The population pressure is pervasive in both public discussion and in the academic field. Relying on Malthus' (1798) population theory and the work of Ehrlich (1968), the population pressure perspective argues that population growth poses pressure on the local and global environments because it increases consumption of energy, water, and other natural resources, and generates more waste and pollution (Bartlett & Lytwak, 1995; Butler, 2015; Catton, 1982). And, immigration, as the major component of population growth in the U.S., increases pressure on local ecosystems and causes populations to exceed the capacity of the local environments to support them (Beck, 1996; Beck, Kolankiewicz, & Camarota, 2003; Cafaro & Staples 2009; Cafaro, 2015; Chapman, 2006; DinAlt, 1997; Garling, 1998; Krikorian, 2008; Population-Environment Balance, 1992; Simcox 1992; Zuckerman, 1999).

Empirical research on the relationship between population growth and environment commonly employs the IPAT (Impact = Population × Affluence × Technology) model (Ehrlich & Holdren 1971) or STIRPAT model (Dietz & Rosa 1994) for environmental impact by regression on population, affluence and technology. Air quality data is frequently examined in research on the environmental consequences of population because data for air quality are more available than data for other environmental domains. Population growth impacts the environment, although the precise nature of the relationship is uncertain. Population is positively associated with air pollution, but the association holds only for some examined pollutants and not others (Cole & Neumayer, 2004; Cramer, 1998; Cramer & Cheney, 2000; Cramer, 2002; Lankao, Tribbia, & Nychka, 2009; Laureti, Montero, & Fernández-Avilés, 2014; Preston, 1996; Price & Feldmeyer, 2012; Squalli, 2009, 2010). In addition to population, economic development, technology, and political system also substantially affect the environment (Commoner, 1972a, b; Preston, 1996; Rudel, Roberts, & Carmin, 2011).

Since immigration is the major source of population growth in the U.S., immigrants have been linked to a variety of local environmental problems. Immigration allegedly increases pressure on sewage treatment, conversion of rural land, natural habitats, and transportation (Garling, 1998), energy consumption, air pollution, water pollution and flooding (Abernethy, 2002; Beck, Kolankiewicz, & Camarota, 2003), as well as food consumption, and chlorofluorocarbon production (DinAlt, 1997). Immigration is hypothesized to harm the environment through three pathways. First is the population pressure pathway, which argues that immigration leads to population growth and that all population growth has negative environmental impact. Immigrant population is potentially more harmful than native population because of higher fertility among immigrants compared to natives (Ehrlich & Ehrlich, 1991).

The second pathway is through assimilation into American consumption patterns. The United States, home to 4.7% of the world's population, consumed 25.3% of all fossil fuels and generated 20.6% of all greenhouse gases in 2000. The 15 nations of the European Union, which enjoy standards of living comparable to the United States, collectively contained 6.2% of the world's population, consumed 14.8% of fossil fuels, and generated 11.8% of greenhouse gases (Ewing, 2004). Some argue that immigrants are particularly harmful to the environment in the U.S. because they adopt American consumption habits (Bartlett & Lytwak, 1995; Beck, 1996; DinAlt, 1997; Hall, Pontius, Coleman, & Ko, 1994; Population-Environment Balance, 1992). However, empirical research indicates that this is not the case. Immigrants, at least in the first generation, do not necessarily adopt American consumerist values (Carter, Silva, & Guzmán, 2013). They also exhibit higher levels of environmental concern than native-born residents (Hunter, 2000), and are more likely to engage in environmentally-friendly behaviors, such as carpooling and energy-saving (Atiles & Bohon, 2003; Blumenberg & Shiki, 2008; Bohon, Stamps, & Atiles, 2008; Chatman & Klein, 2009; Hunter, 2000; Pfeffer & Stycos, 2002; Takahashi, Duan, & Van Witsen, 2017). Therefore, immigration may be less harmful to the environment in the U.S. than the native population.

The third pathway is community disorganization. Social disorganization theories view diminished social control in ethnically heterogeneous communities as one of the adverse effects of immigration (Bursik & Grasmick, 1993; Bursik, 1999; Warner, 1999). Immigrants are often susceptible to environmental harms because they have less income and political clout in order to organize to address environmental issues (Feldmeyer, 2009; Light & Gold, 2000; Steffensmeier & Demuth, 2001; Martinez, 2002; Portes & Rumbaut, 2006; Stowell, 2007). The very foundation of social disorganization perspective, however, is questioned by the findings that immigration may lead to the development of new types of social organization to mediate the negative effects (Chavez & Griffiths, 2009; Lee and Martinez, 2002, 2009; Ousey & Kubrin, 2009; Schnapp, 2015; Sydes, 2017).

Some scholars (Hultgren, 2014; Neumayer, 2006) argue that it is inappropriate to employ environmental reasons in support of calls for restrictions on immigration. Though "green" arguments may be emotionally compelling even in the absence of clear scientific findings, Kraly (1998) asserts that it is important to explore whether the environmental impact of immigration is proportionate or disproportionate to its numbers, separating the effects of immigration from the more general role of population growth.

2.2 Empirical research on environmental impact of immigration

Empirical research specifically on the environmental impact of immigration to the U.S. is limited. To date, there are only five studies and all focus on air quality in the U.S. (Cramer, 1998; Price & Feldmeyer, 2012; Squalli, 2009, 2010; Authors, n.d.). The four studies of other authors employ different combination of air pollutants as indicators of air quality. The most commonly used air pollutants are NO_x, SO_x, CO, and PM_x.

Cramer (1998) investigates the relationship between population growth and air quality, which is measured by the reactive organic gases (ROG), NO_x, SO_x, CO, and PM_{10} in California. He finds that population growth is strongly associated with some sources of emissions but not with others. There is no evidence that the impact of population growth depends on immigration. On the contrary, higher concentrations of immigrants are associated with lower levels of one of the five air pollutants examined. Thus, he argues that increased air pollution mainly comes from the pressure of domestic population rather than immigration. Though the study covers only California, the large population of immigrants in this region justifies his findings in explaining immigration's impact on environment.

Using data for approximately 200 U.S. counties, primarily in urban areas, Squalli (2009) tests the relationship between native-born and foreign-born population and the four commonly used air pollutants. He finds that the size of the U.S.-born population is associated with higher levels NO_2, PM_{10} and SO_2. The size of the immigrant population is associated with lower levels of SO_2 and higher levels of CO. Immigrant population is relatively less harmful to the environment than natives.

Squalli (2010) examines the relationship between immigration and emissions of the same four air pollutants, CO, SO_2 NO_2 and PM_{10}, at the state level. He finds that U.S. states with larger shares of foreign-born residents have lower emissions of not only SO_2, but also NO_2. The higher CO associated with foreign-born population in his county-level study is not present in the state-level study.

Price and Feldmeyer (2012) examine the effects of immigration on local air pollution levels in 183 Metropolitan Statistical Areas. Air pollution is measured by CO, NO_2, Ozone, SO_2, PM_{10}, $PM_{2.5}$ provided by EPA, and an air pollution index is created to combine these six pollutants. Their findings indicate that immigration is not associated with local air pollution levels across any of the seven pollution measures examined, but negatively related to one of the pollutants. Instead, domestic migration and natural population growth are linked to higher levels of three out of seven pollution measures. Population growth from immigration does not have the same pollution effects that accompany domestic migration and natural population growth. This result again provides evidence that immigration has a lesser impact on the natural environment in the U.S., at least in urban areas.

To help establish a causal link between population and air quality, we conducted a spatial panel study of the EPA's Air Quality Index (AQI) from 2007 to 2013. We found a relationship between native-born population and worse air quality, and a relationship between immigrant population and better air quality (Authors, n.d.). Like the other studies discussed here, we were not able to cover the entire U.S. (particularly the non-metropolitan U.S.) in our sample due to the availability of AQI data at county level, and our choice of predictor variables was quite limited in order to maintain the panel nature of the study. This limitation prompts us to take the advantage of the broad coverage of the EQI data across the entire U.S. in this study, although it is cross-sectional in nature.

In spite of their different measures of air pollution, units of analysis and study scopes, the extant literature on the environmental impact of immigration has provided consistent evidence against population pressure arguments that suggest immigration is the major cause of environmental problems in the U.S.

These prior studies provide significant contributions to the debate over environment-immigration relationship. However, they have three major limitations. First, most of these studies do not take into consideration of spatial autocorrelation of air quality. Second, most of them are hampered by the small samples and the focus on metropolitan areas. This is an important limitation because immigrants are increasingly settling in geographically dispersed areas, including rural areas (Kandel & Parrado, 2005). Finally, all the studies treat the immigrant population as a homogenous group. In fact, immigrants to the U.S. are a highly diverse population, with distinct geographic patterns of settlement (Kritz & Gurak, 2015).

This study attempts to address these limitations by a spatial analysis of the association between native and immigrant populations, using a composite air quality index for all the U.S. continental counties. In addition to the comparison between natives and immigrants in general, we examine the association between immigration and air quality in the U.S. by delving deep into the components of immigrant population, including immigrants by origin and immigrants by year of entry. Our research questions are: 1) How are immigrants different from natives in their relationship with air quality? 2) Does the relationship between air quality and immigrants vary by origin of immigrants? 3) Do immigrants exhibit similar relationship with air quality to that of natives through acculturation over time?

3. Data

Our analysis covers the 3,109 counties and county-equivalents in the contiguous U.S. We exclude all counties in Alaska and Hawaii due to the consideration of spatial proximity in spatial modeling.

3.1 Dependent variable

The dependent variable is the air quality index extracted from the EQI, provided by the EPA for all counties in the United States as an estimate of overall environmental quality relevant to human health (U.S. EPA, 2014a). The EQI summarizes information on the wider environment to which humans are exposed, including the air, water, land, built, and sociodemographic environments, and has an index for each of the five domains. Because environmental data were not collected often enough to fully cover all areas at all time intervals, the EQI utilizes a single point estimate to cover the entire 6-year period from 2000 to 2005 for all the U.S. counties.

Our dependent variable is the EQI's air domain. We use the air domain in order to be comparable with previous research on the immigration-environment relationship, which all focuses on air pollution. The air domain of the EQI measures air quality by combining measures and estimates of 6 criteria air pollutants — CO, SO_2, NO_2, ozone, PM_{10}, and $PM_{2.5}$ — and 81 hazardous air pollutants from two sources: the EPA's Air Quality System (AQS) and the National-Scale Air Toxics Assessment (NATA) (U.S. EPA, 2014b). The AQS collects ambient air pollution data from thousands of monitors across the U.S; the NATA constructs air dispersion models for estimating ambient concentrations of hazardous air pollutants at the county and census-tract levels. The values of the air domain index range from -3.24 to 2.79, with the higher values suggesting worse air quality.

The air quality domain of EQI has a number of limitations. First, the air domain of the EQI is a single estimate representing the average of a 6-year period, which limits this study to a cross-sectional analysis. Second, in the AQS data, not all counties monitor air quality, so some data are interpolated, and even in counties that monitor air quality, the specific pollutants measured vary somewhat. Third, the NATA data are based on model estimates that may under-estimate the concentrations of pollutants and are only available at three-year intervals. Nevertheless, the EQI is created by EPA through extensive work from data source selection to data quality and coverage assessment, as well as variable and index construction over years. In addition, the air quality index produced through data reduction approaches can improve statistical efficiency. The biggest advantage of the EQI is the broad coverage of air quality across the U.S. As far as we know, this is the only air quality data that cover all U.S. counties. The EQI, including its air domain, has been used widely by environmental scholars as a measure of environmental conditions (An, Li, & Jiang, 2017; Grabich, Horney, Konrad, & Lobdell, 2015; Jian, Wu, & Gohlke, 2017; Jian et al., 2017; Lavery et al., 2017).

3.2 Independent variables

There are many factors that may affect air quality, among which population is a major concern, as well as geophysical, traffic, industrial, and meteorological factors. This study uses subcategories of population and immigrant population, income, employment by industry, commute time, and location characteristics to predict air quality. Except rural-urban continuum codes (RUCC), all the data are from the U.S. Census 2000. Immigrant population refers to foreign-born population recorded in the U.S. Census 2000.

We divide population into native-born and foreign-born population to compare these two populations regarding their relationship with air quality. Conceptually, immigrant and foreign-born population are not exactly the same term. Practically, these two terms are often used interchangeably. Following prior studies (Cramer, 1998; Price & Feldmeyer, 2012; Squalli, 2009, 2010), we refer to immigrant population as foreign-born population, i.e., first-generation immigrants. In addition, we break immigrants down into major national- or regional- origin groups. More than half of the total immigrants to the U.S. came from Latin America, the majority from Mexico. We identify 13 immigrant populations from regions or countries that account for more than 3% of the total U.S. foreign-born population in 2000, including immigrants born in Mexico, Central America other than Mexico, the Caribbean, South America, Northern Europe, Western Europe, Southern Europe, Eastern Europe, China, Eastern Asia other than China (Korea and Japan), the Philippines, Vietnam, and India. Finally, to capture the influence of acculturation of immigrants, we use a third specification of immigrant population. The U.S. Census 2000 groups immigrants into 8 subcategories by year of entry from before 1965 to March 2000. We employ these categories to represent immigrants' duration of stay.

Economic development has been found to be highly predictive of air quality. Drawing upon previous studies, we include income and employment to represent the economic development. Income per capita was used as the indicator of affluence at state or county level (Cramer, 1998; Cramer, 2002; Squalli, 2009, 2010). We conduct sensitivity tests for different measures of income provided by the Census 2000. The results show average family income is better than income per capita, average household income or median incomes. We include percentages of employment in four major pollution-prone industries: agriculture; mining; manufacturing; and transportation, warehousing, and utilities. Following Price and Feldmeyer's (2012) study, we also include the percentage of commuters in the county who commute for 60 minutes or longer.

To control for county characteristics, we employ rural-urban continuum codes which are used in the study on population effect on land development (Clement &York, 2017) and longitude and latitude, which are statistically significant in the study on the factors of NO_x emissions in Spain (Laureti, Montero, & Fernández-Avilés, 2014). The U.S. Department of Agriculture (USDA) 2003 rural-urban continuum codes classify counties into 9 categories by the population size and degree of urbanization and adjacency to a metro area, with 1-3 indicating metro counties and 4-9 denoting nonmetro counties.

We test for sensitivity and include variables that are the better fits for this study. All the dependent and independent variables have no missing values for all the 3,109 contiguous counties. Annual temperature is also incorporated as a predictor of air quality in some studies (Elliott & Clement, 2015; Price & Feldmeyer, 2012). However, we elect not to use annual temperature because in the 2000 data, temperature is missing for Miami/Dade county (Florida), which has a foreign-born population of over 50 percent. The regression results without this county only change a little in the levels of significance on county characteristics variables, but do not affect the estimation of population variables which are our primary interest. Therefore, we would rather keep this county with high foreign-born population and maintain a full sample of all the continental counties than consider the effect of temperature.

Table 1 displays summary statistics for the entire data set. The U.S. continental counties on average had 80,002 native-born population and 9,926 foreign-born population. Mexico was the largest source country, accounting for nearly 30% of total immigrants. Except Latin America, Europe and Asia were the other major source regions of immigrants. While each of the four parts of Europe contributed at least 3% immigrants, in Asia, a few countries took the lead in immigration. The percentages of employment varied substantially by industry and county.

TABLE 1 ABOUT HERE

Figure 1 shows both the air index and foreign-born population across all the U.S. contiguous counties in 2000. The shaded counties had negative values of air index (indicating better air quality), while the light counties had worse air quality. Counties in the Midwest, West, and Southwest are more likely to have better air quality than those in the Northeast and Southeast. Counties with more than 10 percent of foreign-born population (marked by bigger dots) are scattered primarily in the West Coast, East Coast, and West South Central region. The relationship between air quality and foreign-born population is not straightforward from this map. Immigrants are concentrated in counties with both good and poor air quality across the U.S. in 2000.

FIGURE 1 ABOUT HERE

4. Methods

4.1 Spatial autocorrelation of air quality

According to Tobler's (1970) First Law of Geography, "near things are more related than distant things." Spatial units would therefore influence each other, depending on their location. Spatial autocorrelation of air quality is documented in previous studies (Chen, Shao, Tian, Xie, & Yin, 2017; Havard, Deguen, Zmirou-Navier, Schillinger, & Bard, 2009; McCarty & Kaza, 2015). To measure the degree of this association, we compute Moran's I statistics using GeoDa (Anselin, Syabri, & Kho, 2006). Global Moran's I is a test of overall clustering, summarizing the degree to which similar or dissimilar observations tend to occur near each other (Anselin, 1988).

Spatial weights matrix specifies the spatial structure of the data. Air quality in a county may affect air quality in its neighboring counties more than that in counties farther away. Air quality tends to correlate within a certain distance instead of within the boundary of specific administrative units. Therefore, we use a distance-based weights matrix with a threshold distance of approximately 146 km, which is the minimum threshold necessary to ensure that each county has at least one neighbor. Counties within the centroid distance of 146 km are considered as having influence on each other; counties beyond that distance have no influence. Based on this weights matrix, Moran's I statistics are calculated. The global Moran's I for air index is 0.606 ($p = 0.001$) which indicates a moderately high clustering of like values on air index across all the counties.

To understand where and how the counties cluster, we turn to local indicators of spatial autocorrelation (LISA) statistics. Figure 2 is a LISA map demonstrating local spatial autocorrelation. The darker shaded counties were clusters with positive local spatial autocorrelation, which means they clustered with their neighbors on either high or low air index. The clustering counties in the middle of the U.S. had better air quality (lower air index), whereas those clustering in the east or the west had worse air quality (higher air index).

FIGURE 2 ABHOUT HERE

Both global and local Moran's I test statistics indicate the presence of spatial autocorrelation of air index.

4.2 Spatial models

Using linear regression to predict EQI values is inappropriate because it produces spatial autocorrelation in model residuals (I=.354, p<.000), requiring the use of a spatial model. There are two basic spatial models to address spatial autocorrelation.

Spatial lag model (SLM) accounts for the spatial autocorrelation of the dependent variable by adding a spatial lag term of the dependent variable into the OLS model. The SLM is expressed as:

$$Y = \rho WY + \beta X + \varepsilon \quad (1)$$

Where Y is the vector of dependent variable; X represents a matrix of the explanatory variables; β is the regression coefficient associated with the explanatory variables; and ε is a normally distributed disturbance term. By adding ρWY, which averages the neighboring values of a location to an OLS model, SLM specifies that the dependent variable in a given county is not only affected by the explanatory variables in the reference county, but also affected by the values of the dependent variables in nearby counties. W is the spatial weights matrix capturing the interaction between the counties; WY reflects the spatial lag of dependent variable; ρ denotes the spatial autocorrelation coefficient that represents the effect of WY.

Spatial error model (SEM) includes a spatial autoregressive error term in an OLS model, assuming the spatial spillover only occurs in the error term. The spatial error model is:

$$Y = \alpha + \beta X + \varepsilon + \lambda W\xi \quad (2)$$

Where ξ is a normally distributed error term; $W\xi$ is a spatially lagged error term; and λ denotes a spatial autocorrelation parameter that represents the effect of $W\xi$. Air quality in a given county is affected by both the explanatory variables in the reference county and the omitted random factors in neighboring counties.

We estimate OLS models first and implement diagnostics tests for spatial dependence. Both the ordinary and robust Lagrange Multiplier (LM) tests for lag and error are statistically significant at .0000. Anselin (2005) recommends that the model with the largest value for the LM robust test statistic is a better fit in this situation. Since the value for robust LM error is larger than that for robust LM lag, we thereby present the results of spatial error models only.

Anselin (2005) suggests caution about possible misspecification when both robust LM lag and error statistics are significant. We test different spatial weights and change the basic specification of the models, as well as estimating spatial lag models. All the results show no meaningful difference. As a robustness check, we also estimate a generalized spatial autoregressive model that allows for both spatial spillovers in the dependent variable and the disturbances to be generated by a spatial autoregressive process. The spatial autoregressive model with autoregressive disturbances (SARAR) combines both endogenous interaction effects and interaction effects among the error terms. SARAR is expressed as:

$$Y = \rho WY + X\beta + u \tag{3}$$

$$u = \lambda Mu + \varepsilon \tag{4}$$

where W and M are n × n spatial-weighting matrices; WY and Mu are n × 1 vector of spatial lags; and λ and ρ are the corresponding parameters.

We estimate all the spatial models in GeoDaSpace 1.0 (Anselin & Rey, 2014). The SARAR models are estimated by spatial two-stage least-squares (S2SLS) method. The S2SLS estimator may allow better approximation of the true spatial dependence by fitting multiple spatial lags. We test distance and contiguity weights matrices and find little difference in the results, as other studies have found (Havard, Deguen, Zmirou-Navier, Schillinger, & Bard, 2009; LeSage & Pace, 2014; Saito & Wu, 2016). Therefore, we present the results based on the distance weights matrix with a threshold of 146 km, as used for Moran's I tests.

5. Results

We present the results of the SEM and SARAR models examining the relationship between air quality and the three specifications of immigrant population in tables 2-4. The coefficients of the control variables change little across the three tables.

5.1 Foreign-born population in general

Table 2 shows the results for the first specification of population, i.e., native-born and foreign-born populations. The spatial coefficients ρ and λ are highly significant in the models, which indicates that the models capture the spatial autocorrelation of the data. Accounting for both spatial autoregression in the dependent variable and in the error term, the SARAR model is better than the SEM in terms of pseudo R-squared. All the coefficients are relatively small, corresponding to the narrow range (-3.24 to 2.79) of the values of air index.

The results of both models are very similar. The coefficients of native and immigrant populations are nearly identical in magnitude but opposite in signs at a high level of significance. A larger native-born population is associated with a higher value of air index and thus with worse air quality. On the contrary, a larger foreign-born population is associated with a lower value of air index and thus with better air quality.

Counties with advanced economies are more likely to experience worse air quality. A higher average family income is associated with worse air quality. Employment plays an important role with regard to air quality as well. Employment in agriculture and mining are associated with better air quality. Employment in manufacturing is associated with worse air quality. These differences may reflect the fact that agriculture and mining tend to be located in rural areas with less pollution while manufacturing may be a source of air pollution. This explanation is supported by the negative relationship of rural-urban continuum codes with air index. More rural counties are associated with better air quality. Employment in transportation, warehousing, and utilities is not statistically significant in SARAR model, though significant in SEM. Surprisingly, commute time is negatively related to the air index. Longer commute times correspond to better air quality, which may imply that people who live in more rural areas tend to commute longer distances to urban areas for work. Longitude is significantly related to the air index, while latitude is not. Counties in the east tend to have worse air quality than those in the west, which is clear in Figure 1 and 2.

The results that immigrant population is significantly associated with better air quality and natives are associated with worse air quality are consistent with prior studies. Although population inevitably impose pressure on the environment, immigrant population in general is less harmful to local air quality than native-born population.

TABLE 2 ABOUT HERE

5.2 Foreign-born population by origin

When we break down immigrant population by major sources, we find the relationship between air quality and immigrant population varies by origin of immigrants (Table 3). We primarily focus on the results of SARAR model which is better than SEM, as measured by pseudo-R squared. Mexican immigrants, though accounting for the largest share of immigrants to the U.S., are not associated with air quality. Immigrants from the Caribbean, China, and East Asia other than China (Korea and Japan) are significantly associated with worse air quality, whereas those from Central America other than Mexico, the Philippines, Eastern, Northern, and Western Europe are associated with better air quality. The positive association of some immigrant groups with air quality is much stronger than the negative association of other groups, which results in the overall positive association of immigrants with air quality identified in Table 2. These results demonstrate substantial variations among immigrants by origin in the association with local air quality, which has not yet been examined in previous studies. Due to the cross-sectional nature of this study, the association between immigrant groups and air quality may go two directions, i.e., air quality may affect the settlement of immigrants, or immigrants may affect air quality. Further research is expected to explore why and how origins of immigrants affect their association with air quality in the U.S.

TABLE 3 ABOUT HERE

5.3 Foreign-born population by year of entry

Immigrants may acculturate to American excessive consumption pattern, which increases pressure on the environment. Table 4 presents the results of spatial models that replace the overall immigrant population with immigrant groups by year of entry. Again, we rely on the SARAR model due to the higher pseudo R-square value. Immigrants who came to the U.S. from 1995-2000, those who came from 1975-1979, and those who came before 1965, are significantly associated with better air quality. Immigrants arriving between 1990 and 1994, between 1970 and 1974, and between 1965 and 1969 are associated with worse air quality. The association of immigrants and air quality over time shows no evidence of a consistent linear trend towards assimilation to American consumption behavior. Instead, our results indicate a cohort effect. Immigrants entering in different periods both arrived from and entered into specific social and political circumstances, which can affect their settlement patterns and pathways of assimilation. These differences could create differing associations with air quality. Year of entry is likely to be related to national origin groups as well, since different groups were most likely to immigrate in specific periods.

TABLE 4 ABOUT HERE

6. Conclusion

The claim that immigration particularly harms the environment neither addresses the root cause of the environmental problems nor the immigration issues in the U.S. Empirical research is sorely needed for the debate over the immigration-environment relationship. However, the existing studies are limited in number, methodology, and generalization across the entire U.S. This study examines the relationship between native population, immigrant population, and air quality in the U.S. by using spatial methods to analyze the data for all the U.S. continental counties in 2000.

We find that larger native population is significantly associated with worse air quality, in line with previous studies (Cramer, 1998; Squalli, 2009; Authors, n.d.). Our findings also support the results of existing research that immigrant population is associated with better air quality (Cramer, 1998; Price & Feldmeyer, 2012; Squalli, 2009; Authors, n.d.). In contrast to other studies, where findings of a positive association between immigration and air quality only hold for some pollutants or some regions in the U.S., our findings show clear evidence of an association between immigration and overall air quality across the contiguous U.S. counties, and this association is robust to controls for spatial autocorrelation. We thus provide strong support for the hypotheses that immigrants, overall, do not assimilate into U.S. consumer behaviors and that immigrants do not create social disorganization that prevents communities from addressing environmental concerns.

There are numerous possible explanations for the relationships that we found. The disparity in environmental impact by nativity may be attributable to lower consumption patterns of immigrants than their native counterparts due to lower income or traditional habits, as documented in the literature (Atiles & Bohon, 2003; Blumenberg & Shiki, 2008; Bohon, Stamps, & Atiles, 2008; Chatman & Klein, 2009; Hunter, 2000; Pfeffer & Stycos, 2002; Takahashi, Duan, & Van Witsen, 2017). Immigrants may also serve to revitalize communities and make them more willing or able to address environmental issues, as Price and Feldmeyer (2012) argue. Immigration may also be an effect of air quality; that is, immigrants may be drawn to settle in areas precisely because they have better air quality. Finally, the association may be spurious. For example, a liberal political environment at the state level is conducive to legislation that is particularly welcoming to immigrants, and the same political environment may be equally conducive to measures to improve air quality (Hero & Preuhs, 2007).

We also find the variations among immigrant populations by origin in the relationship with air quality. Being the largest immigrant group, Mexicans were not associated with air quality. Most European immigrant groups, as well as immigrants from Central America and the Philippines, were related to better air quality, while East Asian immigrants were related to worse air quality. Like our overall association between immigration and air quality, these varied associations could have a variety of explanations. If immigrants' overall lesser impact on air quality is caused by their consumption and environmental behaviors, then it makes sense that these behaviors might vary according to immigrants' socioeconomic status or cultural norms. Variation across immigrant groups may also reflect settlement patterns that vary by country of origin. In 2000, Mexican immigrants were increasingly settling in smaller cities and rural areas, while Asian immigrants remained concentrated in a handful of large, and mostly coastal, cities (Massey & Capoferro, 2008). Their urban concentration could explain Asians' association with worse air quality. Socioeconomic and cultural differences could also influence the ability and desire of immigrant groups to settle in areas with better air quality. This variation by origin is a complex relationship and deserves further exploration.

Another interesting breakdown of immigrant population by year of entry shows variation in the relationship with air quality among immigrants staying in the U.S. for various lengths. Existing findings on assimilation and environmental impact are mixed, as some studies argue that immigrants assimilate into American super-consuming habits (DinAlt, 1997; Ehrlich & Ehrlich, 1991; Hunter, 2000) and others find it is not true (Carter, Silva, & Guzmán, 2013). Our results provide no support for the assimilation hypothesis, instead pointing to cohort effects. Immigration cohorts may represent groups who have specific cultural, political, or socioeconomic similarities that shape their consumption patterns and settlement choices. This is all the more likely because immigration cohort is also tied to country of origin.

Our findings have important policy implications. First of all, it demonstrates that in the short run, restrictions on immigration will not produce significant environmental benefit, at least in terms of air quality. This finding is not likely to deter immigration opponents, or end the debate on the environmental consequences of immigration. In the long run, more immigration today does mean a larger native-born population in the future, with potentially negative environmental consequences. Although our findings tell against the theory that first-generation immigrants assimilate into American consumption patterns, the question of what happens with their children is less certain. Some evidence from Canada indicates that consumption patterns of children of immigrants are indistinguishable from those of the rest of the native population (Abizadeh & Ghalam, 1992). Other evidence indicates that living in a multicultural society can lead to patterns of increased consumption (Demangeot & Sankaran, 2012).

The second and more important implication is that the characteristics of a population, including its nativity characteristics, are more important than its size in the association between population and environmental quality. Studies show that population pressure perspective may overestimate the impact of population growth which have much less effect than technology (Commoner, 1972a, b; 1991) and overlooks politics in estimating environmental impact (Rudel, Roberts, & Carmin, 2011). The "treadmill of production" in a capitalist system, which requires ever-increasing levels of consumption to drive economic growth, is a major cause of environmental harm (Kovel, 2002; Park & Pellow, 2011; Schnaiberg, 1980; Speth, 2008). Much research highlights these high levels of consumption among Americans (Blumenberg & Shiki, 2008; Carter, Silva, & Guzmán, 2013; Ewing, 2004; Hunter, 2000; Pfeffer & Stycos, 2002). As demonstrated in this study, native-born population is in sharp contrast with foreign-born population in terms of environmental impact, which may be a result of the differences in consumption patterns among the two groups. To protect the environment, a variety of policies can be considered, including policies that limit population growth. However, our research highlights that modifying Americans' consumption patterns provides a promising approach to both short- and long-term environmental protection.

There are two main limitations of this study. The first is that we use cross-sectional data which fail to capture causal relationship between immigration and air quality. We can only identify the statistically significant association between immigrants and air quality. Another is that the air domain index of EQI is somewhat opaque. EQI was measured only once, so the validity of the air index and its compatibility across counties has not been clearly established. Despite these limitations, our study serves as an important counterpart to existing studies by providing strong supporting evidence for the contention that immigrant population is generally less harmful than native-born population, though population growth in any form increases pressure on the environment. We would suggest that it is worth extending the analysis of the dynamic association of immigration and air quality to grasp the influence of original countries on immigrants in their lives in the U.S. This study also indicates that duration of stay is an important factor in considering the immigration-environment relationship in future research.

Tables

Table 1. Descriptions of Independent Variables

Variable	Observations	Mean	Std. Dev.	Min	Max
Native-Born Population	1,005	211,146	387,838	638	6,419,087
Foreign-Born Population	1,005	36,842	153,296	2	3,474,394
Total Population	1,005	247,998	525,296	659	9,893,481
Percentage of Foreign-Born Population	1,005	6.63	6.96	.09	51.34
Income ($10,000s)	1,005	3.67	.87	1.84	11.10
Percentage of Employment in Manufacturing	1,005	11.58	6.37	.73	39.86
Percentage of Employment in Transportation and Warehousing, and Utilities	1,005	5.21	1.82	1.07	16.87

Table 2. OLS, Spatial Lag and Spatial Error Regression Results (Population Specification 1)

Variable	OLS		Spatial Lag		Spatial Error	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	2.016	.332	.810	.370	2.11	.341
Native-born population	.166***	.027	.140***	.027	.137***	.030
Foreign-born population	-.025	.017	-.021	.017	-.013	.646
Per-capita income	-.544	.460	-.190	.447	-.197	.464
Per-capita income^2	.192	.168	.067	.163	.073	.168
Percent employed in manufacturing	.056**	.023	.018	.023	.018	.026
Percent employed in utilities and transport	.088**	.041	.080**	.040	.071*	.042
Rho (spatial lag)			.368***	.056		
Lambda (spatial error)					.394***	.062
R-squared	.175		.221		.216	
AIC	1080.29		1036.28		1042.33	
Schwartz criterion	1114.68		1075.58		1076.72	
N	1,005		1,005		1,005	

* $P<0.1$, ** $P<0.05$, *** $P<0.01$

Table 3. OLS, Spatial Lag and Spatial Error Regression Results (Population Specification 2)

Variable	OLS		Spatial Lag		Spatial Error	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	1.947	.337	.764	.056	2.063	.346
Total population	.140***	.013	.117***	.013	.122***	.014
Percent foreign-born	-.034*	.019	-.027	.018	-.018	.021
Per-capita income	-.466	.459	-.121	.445	-.127	.462
Per-capita income^2	.163	.167	.041	.163	.048	.167
Percent employed in manufacturing	.057**	.023	.020	.023	.020	.026
Percent employed in utilities and transport	.083**	.041	.077*	.040	.069*	.042
Rho (spatial lag)			.367***	.056		
Lambda (spatial error)					.393***	.062
R-squared	.174		.219		.215	
AIC	1081.6		1038.02		1043.98	
Schwartz criterion	1115.99		1077.32		1078.37	
N	1,005		1,005		1,005	

* P<0.1, ** P<0.05, *** P<0.01

Table 4. Population Characteristics of Counties Included in and Excluded from AQI data

	Included counties			Excluded counties		
	West	Non-West	Total	West	Non-West	Total
Mean population	271,648	235,108	244,181	14,534	29,624	28,296
Mean % foreign-born	11.27%	6.82%	7.93%	6.22%	3.45%	3.69%
% metropolitan	47.84%	70.98%	65.24%	10.36%	27.29%	25.80%
% micropolitan	23.53%	14.77%	16.94%	21.76%	21.49%	21.51%
N	255	772	1,027	193	2,001	2,194

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