THE EFFECT OF AIR POLLUTION ON RESIDENTIAL LOCATION DECISIONS IN METROPOLITAN AREAS

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Introduction

It is evident that over the last century the nation's population has become increasingly concentrated in urban areas. It is also true that over the past few decades, an increasing percentage of the urbanized population resides outside the central city, particularly for high income groups. Much empirical research has investigated the reasons for this outmigration from the central city to the surrounding suburbs. These reasons include such factors as the racial composition of the central city, the accessibility of various income groups to employment, composition of the housing stock, fiscal problems experienced by central city governments, as well as others.

While these factors are important, increasing attention is also being placed on the role of amenities in residential location decisions. The empirical research that considers amenities, such as clean air, has focused on the effect of air pollution on property values in order to estimate the willingness of urban residents to pay for clean air. Rather than concentrating on property values, this paper investigates the effect of the level of air pollution in the central city on the spatial distribution of the population between the central city and the suburbs. Specifically, the hypothesis is that the level of air pollution in the central city has a significant dispersing effect on the population. High levels of air pollution will cause a greater proportion of the population to reside outside the central city as residents try to escape the disamenities associated with air pollution. An empirical model based on data for seventy-six metropolitan areas is developed and estimated using ordinary least squares and instrumental variables. Independent variables are chosen to capture other dispersing or concentrating effects on the population, which include such factors as the racial composition of the central city, measures of the historical development of the metropolitan areas, condition of the housing units, transport and employment, as well as air pollution. The model considers the spatial distribution of the population as a whole and the distribution of low-income and high-income groups throughout the metropolitan area.

Review of the Literature

The research on the effect of air pollution on residential location decisions has centered on the air pollution and property value studies.[1] Individuals reveal their preferences for air quality via their choice of residence, where the price of the house includes a premium for location in areas with cleaner air [3]. The approaches in these studies have been twofold. The first is the use of hedonic housing price models. Individuals maximaize utility subject to a budget constraint. Utility depends on a composite private commodity and housing, represented by a vector of housing attributes. Housing attributes include structural, neighborhood, accessibility, and amenity characteristics.

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[1] See Freeman [3] and Smith [11] for reviews of literature on air pollution.

Housing values are regressed on these characteristics to determine the hedonic or implicit price of the house. The coefficient of the characteristic represents the implicit price, which specifies the change in housing value associated with a change in one of the housing attributes. The hedonic price equation can then be used to calculate the willingness of individuals to pay for improvement in air quality [4].

The second approach has been suggested by Polinsky and Shavell [8]. Assuming a small open city, Polinsky and Shavell consider the utility-maximizing behavior of the individual, where utility is a function of a composite private good, consumption of housing, and an index of amenity characteristics. An indirect utility function is specified which is a function of housing prices at each location, income met of transport costs, and amenities at each location. Using the indirect utility function, the equilibrium rent funtion is derived. The effect of an increase in air quality is to shift the rent schedule upwards, causing the city to expand. With a small open city in equilibrium, each individual has the same level of utility which is independent of location, and property values at any location depend only on amentities and other relevant variables at that location. Thus, the housing value equation can be used to calculate a new rent schedule given changes in air quality at each location.

The empirical specification of the Polinsky-Shavell model [7] has property values in a metropolitan area as a function of characteristics of the household, rather than just housing attributes, as was the case in the hedonic housing price models. The variables include median family income, distance from the central business district, age and condition of the housing units, percent of housing units inhabited by non-whites, income classes, and pollution. The model is also to estimate the willingness of individuals to pay for improvements in air quality.

The majority of the empirical results of the hedonic and Polinsky-Shavell models show that pollution is significantly related to housing values in an inverse manner. The primary debate in the literature regrading these studies is under what circumstances air pollution and property value studies can be used to estimate the benefits of improvments in air quality.[2]

Other research has investigated the relationship between ar pollution and the size of urban areas. Robson has conducted both theoretical and empirical work in this area. In his theoretical work [9] using the utility maximizing decisions of individuals, Robson has found that transport-related pollution leads to cities which are too dispersed, since residents undervalue the costs of commuting by not accounting for their effect on pollution; thus, they live too far from the central business district. Pollution from stationary sources generated by residents leads to cities that are too concentrated, since there are greater external costs in the form of uncompensated disutility of pollution inflicted on others near the center than away from it.

In his empirical work, Robson [10] concentrates on the dispersion of metropolitan areas and its effect on the concentration of pollution. For transport pollution, the concentration of pollution is a function of temperature, the

[2]See Freeman [3] for a specific discussion of the models including three in which pollution did not significantly affect housing values.

dispersion of the metropolitan area, growth of population, and the use of public transport. For stationary pollution, the model is the same as above except that the transport variable is excluded. He finds that all these factors are significant, with temperature, dispersion and transit being negatively related to concentration of pollution, while population growth is positively related. These results lead to the conclusion that policy should promote the dispersion of employment and other destinations of commuters to lower the concentration of pollution. In his theoretical model, Robson considers the impact of pollution on a resident's location decision to be important. However, in his empirical work, he determines that, given the SMSA as the observation unit, there is no evidence to suggest that pollution affects the dispersion of the metropolitan area.

This paper takes the opposite view of Robson in determining whether air pollution affects the spatial distribution of population in metropolitan areas, The empirical research investigating the spatial distribution of the population has neglected the influences of environmental amenities on residential location decisions. Many of these studies use negative exponential density functions, were the population density in a metropolitan area is a function of distance from the central business district. Muth [6] and others [5] have then specified variables in order to explain factors affecting the density functions. Muth examines factors and income of the metropolitan area.

Another approach presented by Bradford and Kelejian [2] has considered those factors affecting the location decisions of low, middle and upper income families based on rent differentials and fiscal surplus differentials between central city and suburbs. The view here is that not only has middle class flight to the suburbs contributed to the deterioration of the central city, but deterioration of the central city creates greater incentive for middle and upper income groups to flee to the suburbs.

The model specified in the next section represents an extension of these models in explaining the location decisions of the metropolitan population. The model specifies variables similar to those in Muth's model, but also includes a measure of air pollution. The model then considers how the location decisions of high and low income groups are affected by this set of variables.

Model Specification

The model includes variables which influence the dispersion or concentration of the metropolitan population in order to determine the choice of residence between central cities and suburbs. Data for seventy-six metropolitan areas were obtained and the following form was adopted:

(1) $$\text{POPCON} = \alpha A^{\lambda}$$

where POPCON is the proportion of the SMSA population that resides in the central city; A is the proportion of SMSA land area that is contained in the central city; and α is a constant which should be unity. The exponent λ determines the distribution of the population between central city and suburbs, and is a linear function of the independent variables discussed below.

Since the dependent variable, POPCON, is concerned with the distribution of the population between the central city and the rest of the SMSA some account had to be taken of the distribution of land area in the SMSA. Thus A controls for the distribution of land area between central city and suburbs which would be expected to be influential in explaining the distribution of the population throughout the SMSA. According to the specification of the model, if the population was distributed throughout the metropolitan area in the same manner as land area, a curve indicating the relationship between POPCON and A would be a 45° line. If this is the case, the value of λ would be one. Large values of λ indicate a lower concentration of the population in the central city, while small values of λ indicate a greater concentration of population in the central city.

Three dependent variables are specified in the model. The first is POPCON, to determine the spatial distribution of the metropolitan population without regard to income group. The variable HFAM is defined as the proportion of SMSA families with income greater than $15,000 that resides in the central city. The variable LFAM is defined as the proportion of SMSA families with income less than $5,000 that resides in the general city. Each of the dependent variables is regressed on the same set of independent variables. This is done in order to distinguish how the independent variables influence different income groups as well as the general population. The independent variables are assumed to be important factors in the residential location decisions of all residents, regardless of income class. However, as discussed below, they may not have the same type of influence on both income groups. Some of the factors might lead to movement away from the central city for high income households while being concentrating factors for low income households. The set of independent variables considers the general chacteristics of the central city and the metropolitan area. In this respect, with the exception of the pollution variable, the variables more closely resemble Muth's designation rather than Bradford and Kelejian's. The independent variables included in the model are listed in Table 1.[3]

PBLAC is included in the model in order to account for flight to the suburbs due to the aversion of whites of locating near a high concentration of the black population in the central city. Yinger [17] reviews evidence that indicates that the black population is much more concentrated in the central city than the white population and concludes that this pattern of racial segregation is consistent with models of discrimination. Blacks are excluded from largely white areas in the suburbs and this exclusion leads to a concentration of

[3]Some of the models reviewed in the previous section have included median family income of the SMSA as a relevant explanatory variable. Muth [6] contends that higher income households will locate farther from the central business district provided the increase in income and its effect on consumption of housing outweighs the increase in transport costs. If marginal transport costs increase with income as high income people value travel time more, and if this outweighs the effect of increased income on housing consumption, then high income households will locate closer to the central business district. However, Muth expects the income elasticity of marginal transport costs to be less than unity, while the income elasticity of housing demand is at least unity; therefore, higher income people will locate farther from the central business district. Wheaton [12] has tested this claim empirically, under the contention that current spatial patterns of location are more attributable to social and racial externalities (and environmental, in this author's view) than to income. Wheaton concludes that the income elasticity of marginal transport costs and the income elasticity of housing demand are similar, and that the spatial bidding for land by different income groups is almost identical. For this reason, and the fact that Muth's empirical work on the spatial distribution of the population found income to be generally insignificant, income was left out of the model.

TABLE 1. Variable Summary and Expected Effects on Population Distributions

Variable	LPOP	LHFAM	LLFAM	DATA SOURCE
PBLAC	dispersing	dispersing	concentrating	[13]
TRANSIT	concentrating	concentrating	concentrating	[13]
NOPLUM	dispersing	dispersing	concentrating	[13]
POPGROW	dispersing	dispersing	dispersing	[1, 14]
CONEMP	concentrating	concentrating	concentrating	[13]
DISP6	dispersing	dispersing	dispersing	[14]
TSPG	dispersing	dispersing	dispersing	[16]

blacks in the central city. This PBLAC is expected to have a dispersing effect on the population as a whole and for high income households. High income households would be primarily made up of whites who locate in suburbs that exclude black residents. Low income residents would primarily be made up of black residents so PBLAC would have a concentrating effect on this group.

TRANSIT accounts for the importance of transportation in residential location decisions, and is used as a proxy for transportation costs, which cannot be directly measured. It is expected that this variable will contibute to greater concentration in the central city. Larger values of this variable reflect greater reliance on public transit and less reliance on the auto. This concentrating effect is expected for the general population and the two income groups.

NOPLUM is concluded as a measure of the condition of the housing units in the central city.[4] It is expected that this variable would have a dispersing effect on the population as a whole and high income families. High income households choose to avoid living in areas where there exists a relatively large portion of substandard housing. Thus high income households would seek to live outside the central city in suburban areas which are more likely to have a more homogeneous housing stock of higher quality. NPOLUM may have a concentrating effect on low income households since these households would occupy the substandard units in the central city. However, NOPLUM may also have a dispersing effect for low income households as these households, given the opportunity, would seek to avoid living in substandard housing, *ceterus paribus*.

POPGROW is used as a measure of the age of the SMSA. It is the ratio of the increase in population between 1920 and 1970 to 1970 population. Higher values of this variable reflect recent growth, which is expected to have a dispersing effect on the general population as well as the two income groups. If the metropolitan area is growing rapidly, most of the growth will take place outside the central city boundaries, and all income groups would be expected to be represented.

[4]NOPLUM may not be the best variable to reflect the condition of the housing stock since only a small proportion of the dwelling units would lack plumbing. A better measure may be the age of the central city housing stock which would be more observable by residents particularly high income residents. Thus the older the housing stock in the central city the more dispersed the population, particularly high income residents. However the age of the housing stock was excluded from the model due to multicollinearity problems that existed when this variable was used. Therefore the choice of NOPLUM was made to reduce the likelihood of multicollinearity in the model.

CONEMP measures the location of employment in order to determine how concentrated employment is in the central city. This variable is expected to have a concentrating effect for all groups, as residents prefer to locate nearer to their places of employment in order to reduce transportation costs.

DISP6 represents a historical measure of dispersion and is defined as follows:

$$\text{(2)} \qquad DISP6 = \frac{\log\ (SMAPOP6/CITYPOP6)}{\log\ (SMAREA/CITYAREA)}$$

where SMAPOP6 represents 1960 population of the SMSA, CITYPOP6 represents the 1960 population of the central city, SMAREA is the land area of the SMSA, and CITYAREA is the land area of central city. Larger values of this variable indicate greater dispersion of the SMSA. This is expected to have a dispersing effect on all groups, reflecting a continuation of past development in the metropolitan area.

TSPG measures the level of air population in the central city, and represents air pollution from stationary sources generated primarily by industry and electricity generating plants. It is believed that TSPG captures the full dimension of air quality perceived by the residents of metropolitan areas since it represents a major point source pollutant which would be generated by the industrial activity that has been concentrated in the central city. It may also be true that residential location decisions are influenced by the deterioration in air quality over recent time periods, however it is believed that TSPG captures this. TSPG would be likely to reflect past levels of air quality given the industrial concentrations in the central city. It is expected that higher levels of total suspended particulates will have a dispersing effect on the general population and the two income groups. As residents perceive the disamenities associated with air pollution in the central city, they will locate in suburban areas with better air quality. This will lead to greater outmigration to the suburbs and away from the "source" of the pollution — the central city. It is expected that high income families have a greater ability to escape inferior air quality as they are more mobile. It is also expected that low income families would desire to escape inferior air quality, given the opportunity. While low income families are more heavily concentrated in the central city, *ceteris paribus,* higher levels of pollution perceived by low income families would have a dispersing effect on their location. This is especially true since they are located near the sources of pollution — the industrial sector in the central city. Since it can be argued that the current dispersion of the population throughout the SMSA can affect the level of TSPG in the central city, estimates using instrumental variables are obtained to account for this and are discussed later.

Empirical Results

Restating equation (1) given the definition of the variables in the previous section yields:

$$\text{(3)} \qquad Y_i = \alpha A^{\lambda}$$

where Y_i is either POPCON, HFAM, or LFAM, and where

$$(4) \qquad \lambda = b_1 PBLAC + b_2 TRANSIT + b_3 NOPLUM + b_4 POPGROW + b_5 CONEMP + b_6 DISP6 + b_7 TSPG$$

In order to empirically estimate the model, equation (3) was linearized by taking logarithms. This yields:

$$(5) \qquad \log Y_i = \log \alpha + b_1 APBLAC + b_2 ATRANSIT + b_3 ANOPLUM + b_4 APOPGROW + b_5 ACONEMP + b_6 ADISP6 + b_7 ATSPG$$

where A represents multiplying each variable by log A.

The signs of the coefficients of each of the variables in equation (5) will indicate whether that particular variable acts to disperse or attract the population to the central city. Positive values fo the coefficients indicate an inverse relationship between the independent and dependent variables. Thus, positive coefficients mean that the variable will have a dispersing effect on the population. Negative values for the coefficients suggest that the variable contributes to a higher concentration of the population in the central city.

Equation (5) was estimated for each of the three dependent variables using ordinary least squares. Table 2 presents the results. In most instances the empirical results support the hypotheses presented in the previous section.[5] In the POPCON equation, the signs of the coefficients show the expected relationships with PBLAC and TRANSIT being significant. In the HFAM equation, all the variables except NOPLUM are significant; however TRANSIT has the opposite sign than expected. In the LFAM equation all the variables are significant and have the expected sign with NOPLUM having a dispersing effect on low income households. In all three equations, the pollution variable shows a highly significant dispersing effect.

Using ordinary least squares assumes that each of the independent variables is exogenously determined and uncorrelated with the error term. However, two of the variables in the model may be endogenous, these being TRANSIT and TSPG; thus, ordinary least squares may yield biased and inconsistent estimators. It can be argued that both of these variables depend on the dependent variable in the model. TRANSIT may depend on whether a large proportion of the population resides in the central city, where there is a higher level of service for travel to the central business district. Likewise, the level of pollution may also depend on how dispersed the metropolitan area is [9, 10]. In general, it would be expected that the greater the concentration of a metropolitan area, the higher the level of pollution in the central city will be. In order to account for the endogeneity of TRANSIT and TSPG, the model was reestimated using the method of instrumental variables.[6]

[5]The coefficient for log α shows a significant negative value. Since α was expected to be one, then the coefficient should not be significantly different from zero. However, the value of log α being significantly different from zero indicates a less than perfect functional form of the model.

[6]Instruments chosen include the SMSA population; mean temperature of the SMSA; mean wind velocity of the SMSA; the proportion of metropolitan employment that is in the manufacturing sector; and a measure of the concentration of manufacturing employment in the central city. These variables were used in addition to the other predetermined variables in equation (5).

TABLE 2. OLS Regression Results

	POPCON	HFAM	LFAM
log α	-.4072	-.3633	-.2697
	(-4.346)[a]	(-2.926)[a]	(-3.867)[a]
APBLAC	.0233	.1296	-.1022
	(.402)	(1.68)[b]	(-2.367)[b]
ATRANSIT	-.0005	.0032	-.0020
	(-.3112)	(1.37)[c]	(-1.55)[c]
ANOPLUM	.0107	.0054	.0101
	(2.0114)[b]	(.763)	(2.553)[a]
APOPGROW	.1171	.1211	.0942
	(4.438)[a]	(3.465)[a]	(4.796)[a]
ACONEMP	-.0032	-.0042	-.0019
	(-5.454)[c]	(-5.40)[a]	(-4.326)[a]
ADISP6	.4563	.7594	.3180
	(5.896)[a]	(7.403)[a]	(5.518)[a]
ATSPG	.0010	.0013	.0008
	(3.919)[a]	(3.613)[a]	(4.15)[a]
R^2	.79	.85	.73

Values in parentheses are t-ratios
[a] significant at the 1% level
[b] significant at the 5% level
[c] significant at the 10% level

Table 3 presents the results using the instrumental variables estimating technique. The results are consistent with the findings of ordinary least squares with two exceptions. In the POPCON equation TRANSIT is now significant while in the HFAM equation, TRANSIT is now of the expected sign but is insignificant.

TABLE 3. Instrumental Variable Regression Results

	POPCON	HFAM	LFAM
log α	-.4526	-.4135	-.3023
	(-4.574)[a]	(-3.183)[a]	(-4.108)[a]
APBLAC	.0560	.1574	-.0690
	.832	(1.78)[b]	(-1.379)[c]
ATRANSIT	-.0042	-.0007	-.0048
	(-1.676)[b]	(-.2033)	(2.60)[a]
ANOPLUM	.0142	.0090	.0129
	(2.452)[a]	(1.183)	(2.999)[a]
APOPGROW	.1180	.1217	.0954
	(4.312)[a]	(3.387)[a]	(4.691)[a]
ACONEMP	-.0037	-.0048	-.0021
	(-5.471)[a]	(-5.437)[a]	(-4.280)[a]
ADISP6	.4469	.7400	.323
	(5.246)[a]	(6.613)[a]	(5.099)[a]
ATSPG	.0013	.0016	.0009
	(3.36)[a]	(3.239)[a]	(3.14)[a]
R^2	.78	.84	.71

Values in parentheses are t-ratios
[a] significant at the 1% level
[b] significant at the 5% level
[c] significant at the 10% level

Summary and Conclusions

The empirical results of the previous section are supportive of the hypothesis that air pollution significantly affects residential location decisions. This is true for the general population as well as for high and low income households. For all groups, the effect leads to dispersion of the population away from the central cities to the suburbs. While this is not unrealistic for high income groups, it does indicate that, given the opportunity, low income groups would also prefer residence in areas away from the source of pollution, the industrial sectors of the central city.

These findings have a number of implications. First, the empirical results indicate that models of the spatial distribution of the population in metropolitan areas should make explicit provision for the inclusion of an environmental quality variable to account for the effect air quality has on the distribution of the population. This has been a neglected feature of these models.

Second, the empirical results indicate that higher levels of air pollution in the central city contribute to outmigration leading to metropolitan areas that are more dispersed than would be the case if the air quality in the city was better. Robson [10] suggested that the dispersion of the metropolitan area affected the concentration of pollution, but could find no evidence of the reverse relationship. The results in this paper support the expectations that air pollution may lead to cities that are too dispersed thus aggravating the problems of urban sprawl that metropolitan areas face.

Third, the results imply that reduction in the level of air pollution may retard somewhat the outmigration of the population to the suburbs. While better air quality alone will probably not reverse outmigration to the suburbs, it does indicate that environmental quality is important, and even though markets for environmental quality do not exist, the results indicate that residents reveal their preferences for it by their choice of residence.

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