Measuring the General Equilibrium Benefits of Air Quality Regulation in Small Urban Areas

Constant I. Tra

Assistant Professor

Department of Economics and the Center for Business and Economic Research

University of Nevada, Las Vegas

Box 6002, 4505 S Maryland Parkway, Las Vegas, NV 89154-6002

Tel: 1-702-895-3191

constant.tra@unlv.edu

This paper is forthcoming in Land Economics

Measuring the General Equilibrium Benefits of Air Quality Regulation in Small Urban Areas

Abstract

We propose a horizontal sorting model for evaluating the benefits of air quality regulation in small urban areas. Previous horizontal sorting models of air quality valuation, because they rely on Census public-use microdata, where the geographic unit of a house is defined by an area of 100,000 people, can only be applied to large urban centers such as Los Angeles. This study combines housing transactions data with household characteristics in order to estimate the benefits of meeting the daily national ambient air quality standard for ozone to Las Vegas area homeowners.

JEL Classification: Q51, R21

Keywords: residential sorting, air quality, welfare

Measuring the General Equilibrium Benefits of Air Quality Regulation in Small Urban Areas

1. Introduction

This study develops a residential sorting model of the Las Vegas housing market in order to estimate the benefits of regulatory efforts aimed at bringing the Las Vegas metropolitan area within compliance of the daily national standard for healthy ozone. Because air quality regulatory programs are mainly implemented by small jurisdictions, such as counties or cities, the benefits and costs of these regulations are likely to vary across the nation as a result of the heterogeneity across populations and housing market conditions. The novel contribution of this paper is to propose an empirical framework for evaluating the benefits of air quality regulations in small urban jurisdictions. The existing environmental valuation studies that utilize equilibrium sorting models typically rely on census (aggregate) data to characterize household heterogeneity across neighborhoods in large metropolitan areas. However, the aggregate household characteristics in census data provide insufficient variation for studies targeting smaller jurisdictions, such as counties or cities, where air quality regulatory programs are actually implemented.

A number of empirical studies have investigated the economic benefits of marginal air quality improvements (see Smith and Huang 1995; Beron, Murdoch, and Thayer 2001; Chay and Greenstone 2005; Neill, Hassenzahl, and Assane 2007). These studies have provided estimates of the marginal willingness to pay (MWTP) for air quality. In contrast, the evaluation of air quality regulations often involves large changes that vary spatially over a region. Residential sorting models (see Sieg et al. 2004; Tra 2010) offer a framework for evaluating such policies. These models allow the researcher to estimate structural parameters of household preferences for amenities and explicitly characterize the housing market equilibrium. Tra (2010) develops a horizontal framework which allows the researcher to explicitly characterize the heterogeneity of preferences for air quality. The sorting model is then used to evaluate the general equilibrium benefits of the 1990 CAAA in the Los Angeles area.

While the existing sorting models provide a readily available tool to evaluate benefits of air quality regulations in large metropolitan regions, they do not provide a framework for evaluating air quality regulations in relatively small urban areas, such as cities and counties, where most air pollution regulatory programs are actually implemented. A limitation of the empirical framework of Tra (2010) is that it relies on the Census Public-Use Microdata Sample (PUMS) which characterizes the household residential location by a Public-Use Microdata Area (PUMA), an area containing approximately 100,000 people. While this approach is acceptable for large regions such as the Los Angeles area, the aggregate household characteristics in the Census PUMS provide insufficient variation for evaluating policy effects in smaller jurisdictions. For these cases, the PUMS microdata do not provide the spatial variation needed to identify household preferences for air quality.[1] This addresses this issue by combining housing transactions data with household characteristics obtained from the Home Mortgage Disclosure Act (HMDA) database.[2] This approach follows the data strategy previously employed by Bayer, Ferreira, and McMillan (2007) who study preferences for neighborhoods and school quality in the San Francisco Bay area. To our knowledge, this methodology has not been applied in the context of air quality valuation. Combining housing transactions with household characteristics provides an added advantage as these data provide a more comprehensive set of housing characteristics and a better spatial characterization of the location choice than the Census PUMS.

Household preferences are estimated in a residential sorting framework by combining housing transactions from the Las Vegas Valley in 2006, household income and racial characteristics obtained from the Home Mortgage Disclosure Act (HMDA), ozone air pollution at each house, math test score of each house's elementary school, and neighborhood demographic composition. Households' residential location choices are characterized by a discrete choice model in which equilibrium conditions are enforced. The model captures the heterogeneity of household preferences for location amenities by incorporating observed household characteristics, in this case household income, in the utility function. Incorporating household income in the utility function allows one to evaluate the distributional effects of a policy.

The empirical welfare findings show both similarities and differences in comparison to residential sorting models of large urban centers. Like Tra (2010) and Sieg et al. (2004), who study the general equilibrium benefits of air quality regulation in Los Angeles, we find that households in smaller jurisdictions place similar values on air quality regulation. In contrast to the Los Angeles sorting models, we find little differences between partial and general equilibrium welfare measures, which may suggest that households in relatively small jurisdictions are less likely to relocate as a result of air quality improvements. Our results also suggest that the benefit of cleanup is higher in cleaner neighborhoods. This is because the high-income households, who reside in cleaner neighborhoods, are willing to pay more for each incremental improvement in air quality. These findings provide further evidence that air quality is a normal good (see Finney, Goetzke, and Yoon 2011) and show that there is wide variation in the benefits of air quality regulation based on income level and neighborhood air quality even in relatively small urban areas like Las Vegas.

2. Data sources

The empirical analysis combines housing transactions from the Las Vegas Valley and household characteristics from the Home Mortgage Disclosure Act (HMDA) in order to estimate household preferences. The housing data are supplemented with ozone air pollution data from the US EPA. We also collect school quality data from the Clark County School District, demographic variables from the 2000 U.S. Census, as well as zip-code data on population, housing, and business establishments. A summary of the main variables used in the empirical analysis is provided in the Appendix (Table A1).

2.1. Household and housing characteristics

The housing transactions data were obtained from two sources. Housing characteristics were obtained from the Clark County Assessor's office. The data provide transaction records for residential properties located in Clark County. Each record includes the property's physical address, history of transactions, transaction sale price, and property characteristics. We matched the housing characteristics with information on mortgage amount and lender obtained from Realquest (www.realquest.com). The housing transactions dataset consists of residential properties sold in the Las Vegas metropolitan area from January 2006 through December 2006. The Las Vegas metropolitan area is a 600 square-mile basin which encompasses the incorporated cities of Las Vegas, North Las Vegas, Henderson, and Boulder City. The housing transaction dataset contains 31,815 single and multi-family owner-occupied residences. Each record includes the property location coordinates, the transaction sale price, and a detailed set of structural characteristics of the home. The house unit sale price is converted to a monthly rental price as follows:

$$p_h = \frac{1}{12} \times \frac{(i+\tau) \cdot Saleprice_h}{1-\left(1+(i+\tau)/12\right)^{-T_h}}. \qquad [1]$$

Where T_h represents the length of the mortgage in months, i represents the annual interest rate on the mortgage, and τ represents the property tax rate. For each house, we obtained the mortgage term, interest rate, and property tax payment in 2006 from the Realquest database.

Housing transactions provide a more precise location for each house and a more comprehensive set of housing characteristics than the housing records available from U.S. Census long form. However, these data do not provide information on the households occupying the houses. As a result, they do not allow one to estimate richer preference specifications, such as those used in Tra (2010), where preferences for location amenities vary across household characteristics. To address this issue, we supplement the housing transaction data with household characteristics available in the HMDA database. These data provide income and race information of the home purchaser. The HMDA was enacted by Congress in 1975 and requires lending institutions to report information on their loan applicants.[3] The HMDA database provides information on the loan applicant (including race and household income), the loan amount, the lender's name, and the census tract in which the property is located. The purpose of the database is to determine whether lending institutions are serving the housing demands of their localities, to assist policymakers in allocating public investments, as well as to identify discriminatory lending patterns. Not all lending institutions are required to report their loan data by HMDA. The 2006 HMDA reporting criteria applied to federally insured or regulated lending institutions (banks, credit unions, or savings associations) with assets of more than $35 million, who had a home or branch office in a metropolitan statistical area.

From the 2006 HMDA database we obtain records from all conventional loan applications approved for the home purchase of an owner-occupied dwelling in Clark County, Nevada. Following Bayer, Ferreira, and McMillan (2007), we then construct an identifier for each record which consists of the lender's unique record number, the loan amount, and the census tract. HMDA records with a unique identifier are then merged with the housing transaction records. From this process we recovered 12,990 housing-unit and household records with non- missing income or race information. Table 2 compares the characteristics of the final housing sample with the original housing transaction dataset. The final housing sample appears to be very representative of the original housing transaction dataset. The mean and median values are virtually the same for sale price, total bedrooms, total bathrooms, lot size, and building size. The median housing-unit age is higher in the final housing sample (6 years) compared to the original housing transaction data (2 years), although the average age is closer across the two samples when one accounts for the standard deviation.

2.2. Ozone air pollution data

The purpose of this study is to evaluate the benefits of ozone air pollution regulation. Ozone air pollution in the Las Vegas Valley is captured via a network of monitors located throughout the area. This pollutant has been shown to have a significant impact on housing prices in Los Angeles (Sieg et al. 2004, Tra 2010). Ozone pollution in 2006 is measured as the highest daily maximum of 8-hour average concentrations at each monitor. Maximum values are used because most of the research in epidemiology and toxicology suggests that the most damages from air pollutants arise from acute episodes of concentrations (Banzhaf 2005). The Clark County air quality monitoring system comprises a total of 16 monitors (See Figure 1).[4] Hence, we rely on interpolation methods to obtain the air pollution measures to each house. We do this by assigning to each house the pollution measure from the closest monitor. Similar interpolation techniques have been used in the literature (see Sieg et al. 2004; Neill, Hassenzahl, and Assane 2007). In previous runs we investigates a distance-weighted interpolation approach, where we assign to each house the distance-weighted average of the ozone reading from the two closest monitors. The two approaches yielded similar results.

2.3. Neighborhood quality data

While it has been shown that ozone air pollution affects housing choices and prices, a number of other neighborhood quality variables are also likely to influence sorting. These include environmental variables, such as traffic, noise pollution, and fine dust, as well as neighborhood economic and demographic characteristics. More importantly, such variables may be partly correlated with ozone pollution so that their omission can potentially bias the estimated preference parameters for air quality. The empirical estimation uses several neighborhood variables as a proxy for neighborhood quality. Neighborhood economic activity is captured by the zip code employment density in 2006, the total zip code business establishments in 2006, the 2004-2006 zip employment growth, and the 2004-2006 zip code business establishments' growth. These variables also control for traffic, noise and fine dust, which are highly correlated with business activity. We also control for neighborhood demographic characteristics using the proportion of minorities in the 2000 Census tract, the median income in the Census tract, the zip code population density in 2006, the zip code housing density in 2006, the 2004-2006 zip population growth, and the 2004-2006 zip code housing growth.

In addition to neighborhood quality, the presence of parks or green spaces may mitigate the negative effects of ozone pollution on house prices. Omission of these characteristics may also potentially bias the preference estimates for air quality. We use two variables to characterize neighborhood open space. The distance from each house to the nearest park is used as a proxy for the access to open space. We also use the interaction of the distance to the closest park with the park's total acreage as a proxy for the amount of open space available at each house.

3. Empirical methodology

The empirical model follows the horizontal sorting framework used by Tra (2010) to evaluate the benefits of non-marginal air quality changes in the Los Angeles area. The household location preferences are modeled according to the random utility framework of McFadden (1978) and the horizontal model of product differentiation of Berry, Levinsohn, and Pakes (1995) which incorporates location-specific unobservables. Each household chooses its residential location h from a discrete set of housing types (H). Each housing type is characterized by its rental price (p_h) and a vector of observed attributes $\boldsymbol{X_h}$. Observed housing attributes include structural characteristics of the house (number of bedrooms, square footage, etc.), and neighborhood variables such as school quality and ozone air pollution. In addition, unobserved characteristics of the housing type are captured by a location-specific error component ξ_h. Households are characterized by a vector of observed characteristics $\mathbf{Z_i}$, which includes the household head's income (y_i) and race. Unobserved heterogeneity among households is captured by the error component ε_{ih}. Each household chooses the residential location which provides it with the highest utility. The household's indirect utility function derived from this maximization problem is given by:

$$V_{ih} = \alpha \log(y^i - p_h) + \sum_{kr} z_{ir} x_{hk} \beta_{1kr} + \mathbf{X_h \beta_2} + \xi_h + \varepsilon_{ih} \qquad [2]$$

Where α, β_1, and β_2 are parameters of the household's preference function to be estimated. We explicitly account for the heterogeneity in households' preferences for location characteristics by allowing the taste parameters to vary systematically across households. The specification of the heterogeneous taste parameters uses interactions between location characteristics and observed characteristics of households.

The parameters of the household utility function specified in [2] are estimated via a multinomial logit. Before proceeding to the estimation strategy, we discuss the assumptions of the empirical sorting model and address practical issues related to the characterization of housing types and the choice set of households.

3.1. Assumptions of the sorting framework

The residential sorting framework makes several implicit assumptions that should be discussed. First, we assume that an individual would have the same income if he/she chooses a different neighborhood location in the Las Vegas metropolitan area. This is not a strong assumption in a small urban area, like Las Vegas, where commuting times are generally not an issue. Hence, an individual would not like likely change jobs when moving to a new neighborhood.[5]

The second implicit assumption of the sorting model is that the housing price, p_h, of a residential location *h* in 2006 is set to the observed transaction price at location *h* in 2006 and is exogenous to the household. This essentially says that the housing market is in equilibrium in 2006 so that an individual choosing a residential location *h* does not affect the price p_h. This assumption is essential to applying the residential sorting equilibrium framework. As stated by

Bayer, Keohane, and Timmins (2009), this assumption represents a cost to this framework. The benefit is that it allows one to estimate rich preference patterns that can provide details insight on the heterogeneity of preferences for amenities, as well as capture non-marginal changes in amenities, either of which cannot be captured in the reduced-form framework of the hedonic model.[6] We should note that our estimation addresses the potential endogeneity of the housing price that would arise if this assumption fails to hold. This is discussed in the estimation issues below. We should also note that the housing price assumption is relaxed in the computation of general equilibrium welfare measures as housing prices are solved endogeneously via simulation.

The equilibrium framework also makes the implicit assumption that the supply of each housing type *h* is fixed, i.e., perfectly inelastic. However, it is quite possible, in theory, that both the price and the quantity of housing will adjust as a result of an amenity change, and that the price response will be bigger (and the quantity adjustment smaller) in areas that have less undeveloped land (Hilber and Mayer 2009). The implication is that the estimate of the MWTP for air quality may be inaccurate given that capitalization will vary across neighborhoods. Following Hilber and Mayer (2009), in the empirical estimation below, we use the zip code housing density as a proxy for the neighborhood's residential land supply elasticity.

The capitalization of amenities in the presence of supply side adjustments is an important theoretical problem with potential ramifications for empirical work. Brasington (2002) develops a theoretical model which shows that there should be a stronger rate of capitalization toward the interior of an urban area, where the housing supply is relatively inelastic, and a weaker capitalization of amenities toward the edge of a city, where more land is available and the housing supply tends to be very elastic. However, the empirical analysis in Brasington (2002) does not fully confirm the hypothesis of their theoretical model. A recent empirical study by Stadelmann and Billon (2012) analyzes this problem in greater detail and shows that it may not be that relevant empirically.

3.2. Characterizing housing types

We use the sample of 12,990 housing units in our merged dataset to characterize the housing product space in the Las Vegas metropolitan area in 2006. Following the approach of Bayer, Ferreira, and McMillan (2007) and Takeuchi, Cropper, and Bento (2008), we assume that each of the 12,990 housing units chosen by the households in our sample represent a housing type and that they are many houses of the same type in the Las Vegas market. This seems to be a reasonable assumption as it was shown (see section 2.1) that the sample was very representative of the housing transactions in the Las Vegas area in 2006.

An alternative to characterizing the housing product space is to use discrete housing types. This is the approach used by Tra (2010) and Klaiber and Phaneuf (2010). While using housing types rather than housing units to characterize residential locations significantly reduces the number of alternatives in the housing market, Tra (2007) has shown that alternative characterization of the product space using smaller versus larger number of housing types yields very similar parameter estimates.

3.3. Determining the choice set of households

The household's relevant choice set or feasible set of alternatives is an essential component of the estimation. A sampling approach is also used to construct the choice set. Potentially, one could set the household's choice set as the 12,990 housing types in the sample. However, this would render the estimation computationally intractable. The reason is that the computational burden of the estimation grows linearly with the size of the household's choice set (Ben-Akiva and Lerman, 1985). An alternative is to construct the choice set by sampling a few alternatives from the full set of available alternatives. In particular, the household's choice set includes (i) the household's chosen residential location and (ii) a random sample of 100 residential locations from the remaining non-chosen alternatives. McFadden (1978) has shown that such a scheme will yield consistent parameter estimates for the multinomial logit model.

3.4. Estimation of the household preference parameters

The parameters ($\alpha, \boldsymbol{\beta_1}, \boldsymbol{\beta_2}$) of the household indirect utility are estimated from a multinomial logit model. The mechanics of the estimation require rewriting the indirect utility in [2] as:

$$V_{ih} = \alpha \log(y^i - p_h) + \sum_{kr} z_{ir} x_{hk} \beta_{1kr} + \delta_h + \varepsilon_{ih}, \qquad [3a]$$

$$\delta_h = \sum_k x_{hk} \beta_{2k} + \xi_h. \qquad [3b]$$

Where δ_h is a location-specific constant which represents households' common valuation of the residential attributes. This valuation is shared by households regardless of their characteristics. The estimation follows a two-stage approach. In the first stage, we the estimate (*J-1*) location-specific constants[7] (δ_h) and the parameters ($\alpha, \boldsymbol{\beta_1}$) characterizing the household-specific tastes, via maximization of the log-likelihood:

$$L(\boldsymbol{\delta}, \alpha, \boldsymbol{\beta_1}) = \sum_{i=1}^{N} \sum_{h \in C_i} I_{ih} \log P_{ih}(p_h, x_h, z_i; \boldsymbol{\delta}, \alpha, \boldsymbol{\beta_1}), \qquad [4]$$

where I_{ih} is a dummy that equals 1 whenever household i chooses location h in the data, and C_i represents the choice set of household i. P_{ih} represents the multinomial logit probability that household i chooses housing product h, and is given by:

$$P_{ih}(p, z_i, x; \boldsymbol{\delta}, \alpha, \boldsymbol{\beta_1}) = \frac{\exp[\delta_h + \alpha \log(y_i - p_h) + \sum_{kr} x_{hk} z_{ir} \beta_{1kr}]}{\sum_{m \in C_i} \exp[\delta_m + \alpha \log(y_i - p_m) + \sum_{kr} x_{mk} z_{ir} \beta_{1kr}]}. \qquad [5]$$

In practice, the maximization of the log-likelihood in [4] with respect to the 12,990 location-specific constants and household-specific parameters (α, $\boldsymbol{\beta_1}$) is computationally demanding.[8] A contraction mapping proposed by Berry, Levinsohn, and Pakes (1995) allows one to circumvent this computational burden by solving for the alternative-specific constants separately using the first-order conditions of the log-likelihood function. The second-stage estimates the vector of mean taste parameters ($\boldsymbol{\beta_2}$) in a least-square regression using the estimated vector of alternative constants as the dependent variable:

$$\hat{\delta}_h = \sum_k x_{hk} \beta_{2k} + \xi_h . \qquad [6]$$

The underlying assumption of the second-stage regression is that the housing and neighborhood attributes in x_h are uncorrelated with the unobserved attributes of the residential location. The consistency and asymptotic normality of the first and second-stage estimations are established in the technical appendix provided by Bayer, Ferreira, and McMillan (2007).

As we mentioned previously, a potential bias may arise, in the second-stage regression, when unobservable neighborhood disamenities are correlated with neighborhood air pollution. For instance, local economic activity is likely to be correlated with neighborhood air quality and housing prices (Bayer, Keohane, and Timmins 2009). As a result, the ozone pollution variable may be endogenous. Chay and Greenstone (2005) and Bayer, Keohane, and Timmins (2009) developed instrumental variables (IV) approaches based on national county-level data. However, these IV methods are not applicable in a local setting. In this study we address this issue by including several neighborhood variables in an attempt to capture various types of neighborhood disamenities. These neighborhood variables are described in section 2.3.

Some horizontal sorting models (see Bayer, Ferreira, and McMillan 2007; Klaiber and Phaneuf 2010) have used an instrumental variable (IV) approach to deal with the potential endogeneity problem that arises when the housing price enters the second stage. This endogeneity is caused by the fact that housing prices could be correlated with unobserved characteristics of residential locations. This is not the case in our specification, as housing prices only enter the first-stage estimation via the non-linear term *log(income – rental price)*. The presence of residential location fixed effects in the first-stage estimation will eliminate the potential bias that would arise from the correlation between housing prices and unobserved characteristics of residential locations.[9] Hence, our identification of the income effect relies on the log functional form assumption. This approach was also used by Takeuchi, Cropper, and Bento (2010) and Tra (2010). A similar strategy was used by Bayer, Keohane, and Timmins (2009). Alternative functional form assumptions (such as square root) are investigated as a robustness check.

Finally, some authors have found that controlling for employment locations substantially improves the fit of the residential sorting models to the data (see Bayer, McMillan, and Rueben 2004; Takeuchi, Cropper, and Bento 2010). However, the extent to which inclusion of the household employment location alters the estimated preference parameters is not clear. Tra (2007) estimates a residential sorting model of the Los Angeles area and finds that controlling for the household's employment zone has little effect on the key preference parameters of the sorting model. While controlling for employment location may matter in large urban areas such as Los Angeles, this is less likely to be the case in metropolitan areas with small geographic boundaries, such the Las Vegas area, were commuting distances are generally short and congestion during peak hours is not a major issue.

3.5. Sorting model estimates

Table 3 summarizes the results of the estimation. Additional robustness checks are shown in the Appendix (Table A2). Panel A of Table 3 shows the first-stage estimates of the household-specific taste parameters. We find that households with higher income levels have a higher valuation for air quality and school quality. This is in accordance with the hypothesis that air quality and school quality are normal goods. This result fall in line with empirical results in Tra (2010) and Finney, Goetzke, and Yoon (2011), and is consistent with the location theory of urban land use (Alonso 1964). Panel B shows the second-stage common taste parameters. The second-stage taste parameters generally have the expected signs. On average, households are found to prefer more bedrooms, a pool, a larger lot, more bathrooms, a fireplace, better school quality, and better air quality.

Using the indirect utility in [2], the mean MWTP for a change in air quality (Δq) is given by[10]:

$$MWTP = \frac{\partial \overline{V}_{ih} / \partial q}{\partial \overline{V}_{ih} / \partial y} \Delta q \, . \qquad [7]$$

The results in Table 3 suggest that the estimated MWTP for air quality is robust with respect to the inclusion of neighborhood amenities and disamenities. The mean MWTP is $98/year, compared to $101/year when controlling for neighborhood sociodemographics, neighborhood economic activity and neighborhood parks. While empirical studies using national data (see Chay and Greenstone 2005; and Bayer, Keohane, and Timmins 2009) find that controlling for the endogeneity of air quality leads to larger estimates of the MWTP for air quality, our result may be an indication that the endogeneity of air pollution is not a serious issue in a small urban setting.

The estimated MWTP of $101 for ozone pollution falls somewhat in the in middle of the wide range of estimates in the existing hedonic literature on air quality. Estimates of the MWTP for air quality range from $18 to $280, in 2006 dollars, in the hedonic literature (Sieg et al., 2004). The MWTP estimates in this study are also comparable to recent estimates of the MWTP for ozone air pollution. Using a hedonic approach, Banzhaf (2005) finds a MWTP for a 1% change in ozone-free days ranging from $49 to $140/year when inflated to 2006 dollars. Applying a residential sorting model to the same data as Banzhaf (2005), Sieg et al. (2004) find a MWTP of $94 for a 1% change in ozone concentrations in the Los Angeles area. Tra (2010) also uses a residential sorting model and finds a MWTP range of $52 to $77/year, in 2006 dollars, for a 1% reduction in ozone concentration in the Los Angeles area.

4. The benefits of ozone regulation the Las Vegas Valley [11]

Much of the Las Vegas Valley experienced violations of the daily national standard for healthy ozone during 2006. The area experienced a total of 25 unhealthy ozone days. The mean annual 8-hour maximum ozone concentration across the valley was 0.083 parts per million (ppm), which compares to the 2008 national standard of 0.075 ppm. Ozone concentrations in 2006 also vary substantially across the Las Vegas valley ranging from a low of 0.054 ppm to a high of 0.09 ppm. Hence, bringing the area within daily compliance of the 2008 ozone daily national standard would represent a substantial non-marginal improvement in environmental quality. While hedonic models provide a measure of the incremental willingness to pay (WTP) for small changes, these models cannot appropriately capture the benefits of non-marginal changes.[12] The residential sorting model in this study provides a framework for valuing such changes.

We estimate the benefits, to households in 2006, of bringing the Las Vegas area within full compliance of the daily national standard for 8-hour ozone. We define, in a stylized manner, full compliance as when the 2006 daily maximum 8-hour ozone concentration at each location is capped at the national daily standard (0.075 ppm). This is also equivalent to saying that the number of unhealthy days, in terms of 8-hour ozone concentrations, at all locations is reduced to zero. We begin by discussing the computation of the welfare measures.

4.1. Welfare computation

We use the horizontal sorting model estimated in Section 3 to evaluate the benefits of ozone regulation, mandated by the 1990 Clean Air Act Amendments, to Las Vegas area households. For the purpose of evaluating the benefits of the changes in air quality across the Los Angeles area two welfare measures are of interest. The first measure asks what households are willing to pay for the change in air quality at their residence, holding housing prices and all other attributes fixed. We will refer to this welfare measure as the partial equilibrium WTP measure (WTP^{pe}). For a policy regime which leads to ozone air pollution reductions from x_h^0 to x_h^1, WTP^{pe} is implicitly defined by:

$$\underset{h}{Max}\left\{v_{ih}(y_i - p_h^0, \mathbf{x_h^0}, \varepsilon_{ih})\right\} = \underset{h}{Max}\left\{v_{ih}(y_i - p_h^1 - WTP_i^{pe}, \mathbf{x_h^1}, \varepsilon_{ih})\right\}. \qquad [8]$$

The superscript zero indicates the 1990 market conditions, and the superscript one indicates the market conditions after the air quality changes. The partial equilibrium WTP measure does not, however, provide a complete picture of the welfare impact of the changes in air quality across the Los Angeles area. Bartik (1988) shows that WTP^{pe} provides a lower bound to the full, i.e. general equilibrium, welfare impact of the air quality changes. The general equilibrium welfare measure incorporates induced changes in housing prices that would result from the non-marginal improvement in air quality across the Las Vegas area. These induced housing price changes are obtained by simulation using the procedure described by Tra (2010). This essentially entails simulating the counterfactual equilibrium which would have emerged in 2006 if the ozone level at each location was capped at the national daily standard, while all other housing attributes and household characteristics remained at their 2006 levels. The general equilibrium welfare measure (WTP^{ge}) is implicitly defined as:

$$\underset{h}{Max}\left\{v_{ih}(y_i - p_h^0, \mathbf{x_h^0}, \varepsilon_{ih})\right\} = \underset{j}{Max}\left\{v_{ij}(y_i - p_j^1 - WTP_i^{ge}, \mathbf{x_j^1}, \varepsilon_{ij})\right\}. \qquad [9]$$

The household's residential location choice *j* in the *ex-post* equilibrium differs from the location *h* in the benchmark equilibrium, implying that the household might change its residential location choice as a result of the change in air quality.

The computation of the welfare effects holds the housing supply fixed. The implication of this assumption is that the computed WTP measures would reflect the short-run benefits of the policy change (Takeuchi, Cropper, and Bento 2008). The assumption of fixed housing supply may be too strong if the housing supply is very elastic and new houses are built in areas with lower air pollution. This would imply that the elasticity of the housing supply with respect to air quality is very high. While we do not have empirical estimates of the elasticity of the housing supply with respect to air quality, we checked for the empirical correlation between ozone air pollution and the 2004-2006 zip code housing growth in the Las Vegas valley. The correlation coefficient is 0.04, which suggests that the elasticity of the housing supply with respect to air quality is likely to be very low in the study area.

4.2. Welfare results

Table 4 presents the mean partial equilibrium and general equilibrium benefits of meeting the 2008 8-hour daily ozone standard of 0.075 ppm. The average daily maximum 8-hour ozone level in the Las Vegas valley during 2006 was 0.083 ppm. Columns (VI) through (IX) show the general equilibrium impacts of the air quality improvements. We find that meeting the 2008 air quality standard was worth on average $1,644 per year for each household. The partial equilibrium welfare measures are shown in columns (III) through (V). These welfare measures capture the direct welfare impact of the air quality change on households, while ignoring the fact that the underlying sorting equilibrium may change. Allowing households to relocate after the air quality changes leads to higher welfare gains, on average. This is consistent with the theoretical result in Bartik (1988) and the empirical findings in Sieg et al. (2004) and Tra (2010). However, the partial equilibrium welfare effects do not differ substantially from the general equilibrium WTP measures. This is unlike Tra (2010) who finds that the mean general equilibrium WTP is almost 20% higher than the partial equilibrium mean WTP. This divergence of findings may be explained by the small housing price changes in this study (see column VI), which suggests that the air quality improvements do not cause many households to change their location choices.

In addition to presenting the mean welfare benefits of air quality for households across Las Vegas, Table 4 provides additional information with respect to the distribution of welfare estimates. Columns (VIII) and (IX) show the general equilibrium WTP for the top and bottom quartiles of the household income distribution. For the lowest quartile (bottom 25%), we find a mean general equilibrium WTP of $360, which compares with a mean general equilibrium WTP of $4,656 for the highest quartile (top 25%) of the income distribution.

The last two rows of Table 4 show the benefits of cleanup across the least polluted neighborhoods and the neighborhoods with the most ozone pollution. These two rows show that the mean WTP in the cleanest neighborhoods (bottom 10% in ozone levels) is substantially higher than the mean WTP in the neighborhoods with the worst air quality. This finding is consistent with Tra (2010) and is partly due to two factors. First, households in the cleaner neighborhoods have on average higher income and as a result place a higher value on air quality improvements. The second factor contributing to the higher benefits in the cleanest areas is due to the fact these areas experience a decrease in housing prices in the household sorting that follows after the air quality improvements, whereas the most polluted areas experience an increase in housing prices after sorting (see column VI).

The last two rows of Table 4 also suggest that there is substantial heterogeneity across income groups with respect to the way that the benefits air quality regulation vary across the neighborhoods. Indeed, while low-income households in cleanest and most polluted areas experience similar benefits (columns IV and VIII), we find that benefits of the regulation are almost twice as much for rich households in the cleanest neighborhoods as compared to rich households in the most polluted neighborhoods (columns V and IX). This could be due to the fact that rich households have a better ability to relocate while poor households may be less mobile as their housing choices may be limited. This finding differs from Tra (2010) who finds little variation in benefits across neighborhood ozone levels for both poor and rich households. This divergence in findings is likely due to the relatively coarse spatial characterization of neighborhoods in Tra (2010) where housing locations are defined by the Census PUMA.

Table 5 reports the benefits of meeting the 2008 daily national ozone standards across the incorporated cities of the Las Vegas Metropolitan area. We find substantial variation in benefits across the cities. The mean general equilibrium WTP in the city of Las Vegas, the largest incorporated area is $1,656. In contrast, the city of North Las Vegas, the incorporated area with the lowest average income and the highest average ozone pollution, the mean general equilibrium WTP is $1,020. The largest mean general equilibrium WTP is found in Henderson, the city with the highest average income in the valley.

The benefits of air quality regulation in this study can be compared with Tra (2010), Sieg et al. (2004), and Smith et al. (2004) who estimated general equilibrium benefits of ozone reductions in the Los Angeles area, a large urban area known for serious ozone problems. For the ozone reductions which took place between 1990 and 1995, Tra (2010) identifies annual benefits for the Los Angeles area of about $1,156 per household, in 2006 dollars, and compares his result with empirical evidence reported by Sieg et al. (2004) for a mean benefit of $1,850 per household, in 2006 dollars. While recognizing that the welfare measures are based on different reductions in ozone pollution, our annual general equilibrium WTP for meeting the 2008 daily ozone standard of $1,644 per household in the Las Vegas area appear to be fairly similar. In addition, we find that the wide variation in air quality benefits, across income and locations, which is observed in the Los Angeles area by Tra (2010) and Sieg et al. (2004) also emerges in a relatively small urban setting like the Las Vegas Valley. The welfare estimates for meeting the 2008 ozone standards also compare with Smith et al. (2004) who report a range of $50 to $3,700 across different school districts in the Los Angeles area, in 2006 dollars. This analysis provides new evidence on the benefits of air quality regulation, for small urban jurisdictions like the Las Vegas Valley. We show that even in these relatively small urban areas, households value air quality regulation and that these values vary substantially by location and household income.

5. Conclusions

Benefit estimation is a necessary tool for the evaluation of environmental regulations. However, current estimates of the benefits of air quality regulation are only available for large regions such as, Los Angeles. This study uses a horizontal sorting model to evaluate the benefits of meeting the national daily ozone air quality standard in a small urban area. Previous horizontal sorting models of air quality valuation (e.g. Tra 2010), because they rely on Census PUMS microdata where the geographic unit of a house is defined by an area of 100,000 people, can only be applied to large urban centers. This study combines housing transactions data with household characteristics in order to estimate the benefits of air quality regulation in a small urban area. The empirical welfare findings show both similarities and differences in comparison to residential sorting models of large urban centers. Like Tra (2010) and Sieg et al. (2004), who study the general equilibrium benefits of air quality regulation in Los Angeles, we find that households in smaller jurisdictions place similar values on air quality regulation. In contrast to the Los Angeles sorting models, we find little differences between partial and general equilibrium welfare measures, which may suggest that households in relatively small jurisdictions are less likely to relocate as a result of air quality improvements.

For local jurisdictions such as Clark County, planners contend with difficult tradeoffs. They are required to implement plans to meet standards to avoid economic sanctions from nonattainment such as the loss of highway funds or stigma associated with lower environmental quality for individuals considering a move to the area. They also must contend with complaints from citizens and business leaders who point out there are additional and significant costs of meeting higher standards. Finally, they are responsible for meeting with community leaders who advocate for cleaner air for more vulnerable populations, such as the elderly and children. To make matters more complicated, areas such as Las Vegas have experienced a prolonged recession since 2008, and there are legitimate concerns with respect to the implications of higher costs to meet air quality standards. Nevertheless, our results provide evidence that there are significant and quantifiable welfare benefits associated with ozone regulation in these local housing markets.

Given the push to raise environmental standards on pollutants such as ground-level ozone, and given the economic problems caused by a prolonged recession there is a need for more information on the benefits of regulation in small metropolitan areas, like as Las Vegas, which are often overlooked in empirical studies. This study suggests that the regulation of ground-level ozone does yield substantial benefits to households even in a small urban setting like the Las Vegas Valley. The study also provides additional benefit information that is often overlooked such as the fact that the benefit of cleanup is higher in cleaner neighborhoods because high-income households tend to value improved air quality more than low-income households. The empirical framework developed in this study can be easily applied to assess the benefits of air quality regulation in jurisdictions of any size (small or large). Housing transactions are typically available from local assessors or private vendors, and the HMDA database is freely available to anyone.

Appendix

Table A1: Descriptive Statistics for the Estimation Sample

Variables	Mean	Std. Dev.	Units	Source
Households:				
Annual household income	121,910	131,500	Dollars/year	HMDA
Minority (Black or Hispanic)	0.29	0.45	Binary	HMDA
Housing units				
Sale price	357,719	146,128	Dollars	Clark County Assessor
Monthly rental price	2,273	899	Dollars/month	Calculated from sale price
Bedrooms	3.31	0.82	-	Clark County Assessor
Bathrooms	2.62	0.72	-	Clark County Assessor
Lot size	0.14	0.10	Acres	Clark County Assessor
Age	10.97	13.44	Years	Clark County Assessor
Pool	0.20	0.40	Binary	Clark County Assessor
Fireplace	0.50	0.50	Binary	Clark County Assessor
Single-family unit	0.92	0.27	Binary	Clark County Assessor
Neighborhood quality:				
ozone 8-hour daily max value	0.08	0.01	Parts per million (ppm)	US EPA AirData
Proportion of 4th grade students proficient in math	0.57	0.14	-	Clark County School District
Census tract average income	5.63	1.51	Ten-thousand Dollars/year	2000 US Census
Census tract proportion of minorities	0.21	0.17	-	2000 US Census
Zip code population density in 2006	15.69	9.95	Thousands/km^2	Clark County Comprehensive Planning
Zip code housing density 2006	6.09	3.85	Thousands/km^2	Clark County Comprehensive Planning
Zip code population growth 2004-2006	36.52	258.88	Percent	Clark County Comprehensive Planning
Zip code housing growth 2004-2006	14.21	94.51	Percent	Clark County Comprehensive Planning
Zip code employment density 2006	0.79	1.48	Ten thousands/km^2	Zip-code Business Patterns
Zip code business density 2006	0.38	0.49	Thousands/km^2	Zip-code Business Patterns
Zip code employment growth 2004-2006	1.01	2.65	Percent	Zip-code Business Patterns
Zip code business growth 2004-2006	0.78	1.91	Percent	Zip-code Business Patterns
Distance to closest park	2.72	2.69	Kilometers (km)	Clark County GIS Management Office
Park acreage	18.86	28.55	Acres	Clark County GIS Management Office

Table A2: Additional Robustness Checks for the Sorting Model Estimates

	Benchmark Specification [i]		Robustness: Choice set [ii]		Robustness: Functional Form [iii]	
First-Stage MLE						
	Coef.	T-stat	Coef.	T-stat	Coef.	T-stat
Log(household income – rental price)	9.01	123.91	9.16	124.77	11.59	173.43
Ozone air pollution * Household income	-3.93	-4.02	-3.77	-3.77	-4.06	-4.19
4th grade students proficient in math * Income	0.20	4.39	0.21	4.60	0.30	6.31
Log-Likelihood	-57163		-48,157		- 56,950	
McFadden pseudo-R^2	0.22		0.27		0.45	
Second-Stage OLS [iv]						
	Coef.	T-stat	Coef.	T-stat	Coef.	T-stat
Intercept	-3.03	-24.65	-3.10	-24.46	-4.78	-24.91
Bedrooms	0.24	22.79	0.24	22.23	0.31	18.30
Pool	0.38	18.43	0.39	17.87	0.62	17.67
Age	-0.02	-22.64	-0.02	-22.36	-0.03	-19.63
Lot size	4.87	24.33	4.96	23.94	8.04	24.93
Condo (vs. single-family dwelling)	-0.28	-10.66	-0.30	-10.89	-0.27	-6.57
4th grade students proficient in math	1.07	17.20	1.09	17.03	1.67	16.78
Bathrooms	0.45	31.60	0.46	30.79	0.80	33.10
Fireplace	0.39	25.20	0.40	24.90	0.60	24.61
Census tract proportion of minorities	-0.27	-3.74	-0.24	-3.16	-0.09	-0.77
Census tract median income	5.0E-06	7.37	5.0E-06	7.48	7.0E-06	6.16
Zip code population density in 2006	-3.8E-05	-7.96	-4.0E-05	-8.15	-5.6E-05	-7.46
Zip code housing density 2006	8.8E-05	6.81	9.3E-05	6.96	1.3E-04	6.08
Zip code population growth 2004-06	0.02	8.56	0.02	8.42	0.04	8.72
Zip code housing growth 2004-06	-0.07	-8.49	-0.07	-8.35	-0.11	-8.66
Zip code employment density 2006	-4.0E-06	-1.67	-3.0E-06	-1.53	-7.0E-06	-1.91
Zip code business density 2006	2.9E-04	4.77	2.9E-04	4.72	4.3E-04	4.31
Zip code employment growth 2004-06	0.02	2.48	0.02	2.63	0.02	1.89
Zip code business growth 04-06	0.09	5.02	0.09	4.85	0.15	5.53
Ozone air pollution	-8.02	-6.86	-8.02	-6.65	-14.60	-7.96
Distance to closest park	0.07	14.90	0.07	14.67	0.11	14.31
Distance to closest park * Park acreage	4.9E-04	5.41	5.2E-04	5.64	6.7E-04	4.37
R^2	0.75		0.72		0.72	
Implied MWTP for air quality ($/year) [v]	104		101		90	

[i] Benchmark specification used in the welfare analysis. [ii] Characterizes the household's sampled choice set using 50, instead of 100, randomly sampled non-chosen alternatives. (see Section 3.3). [iii] We assess the robustness of our estimates with respect to the functional form of the (income – rental price) term. In this specification, log(income – rental price) is replaced by sqrt(income – rental price). [iv] Second-stage standard errors are computed using White's robust covariance matrix. [v] Constant 2006 dollars. MWTP for a 1 percent reduction in the mean 2006 ozone air pollution level.

Acknowledgments

I am grateful to Mary Riddel, and two anonymous reviewers for valuable comments and suggestions. I also thank Helen Neil, Charles Towe, Shruti Tandon, Bob Potts, and the Center for Business and Economic Research at the University of Nevada, Las Vegas for assistance with the data collection. All remaining errors are mine.

References

Alonso, William. 1964. *Location and Land Use*. Cambridge, MA: Harvard University Press.

Banzhaf, H. Spencer. 2005. Green Price Indices. *Journal of Environmental Economics and Management* 49(2), 262-280.

Bartik, Timothy. 1988. "Measuring the Benefits of Land Improvements in Hedonic Price Models." *Land Economics* 64(2): 172-183.

Bayer, Patrick, Fernando Ferreira, and Robert McMillan. 2007. "A Unified Framework for Measuring Preferences for Schools and Neighborhoods." *Journal of Political Economy* 115(4): 588-638.

Bayer, Patrick, Nathaniel Keohane, and Christopher Timmins. 2009. "Migration and Hedonic Valuation: The Case of Air Quality." *Journal of Environmental Economics and Management* 58(1): 1-14.

Bayer, Patrick, Robert McMillan, and Kim Rueben. 2004. "An equilibrium model of sorting in an urban housing market." Working Paper 10865. Cambridge, MA: National Bureau of Economic Research.

Ben-Akiva, Moshe, and Steven R. Lerman. 1985. *Discrete Choice Analysis: Theory and Application to Travel Demand*. Cambridge, MA: MIT Press.

Beron Kurt, James Murdoch, and Mark Thayer. 2001. "The Benefits of Visibility Improvements: New Evidence from the Los Angeles Metropolitan Area." *Journal of Real Estate Finance and Economics* 22(2): 319-37.

Berry, Steven, James Levinsohn, and Ariel Pakes. 1995. "Automobile Prices in Market Equilibrium." *Econometrica* 63(4): 841-890.

Brasington, David M. 2002. "Edge versus center: Finding common ground in the capitalization debate." *Journal of Urban Economics* 52(3): 524-541.

Chay, Kenneth. Y., and Michael Greenstone. 2005. "Does Air Quality Matter? Evidence from the Housing Market." *Journal of Political Economy* 113(2): 376-424.

Finney, Miles M., Frank Goetzke, and Mann J. Yoon. 2011. "Income Sorting and the Demand for Clean Air: Evidence from Southern California." *Land Economics*, 87(1), 19-27.

Hanemann, W. Michael 1983. "Welfare Measures for Discrete Choice Models." *Economics Letters* 13(2): 129-136.

Hilber, Christian A.L., and Christopher Mayer. 2009. "Why do households without children support local public schools? Linking house price capitalization to school spending." *Journal of Urban Economics* 65 (1):74–90.

Klaiber, H. Allen, and Daniel J. Phaneuf. 2010. "Valuing Open Space in a Residential Sorting Model of the Twin Cities." *Journal of Environmental Economics and Management* 60(2): 57-77.

McFadden, Daniel. 1978. Modeling the Choice of Residential Location. In *Spatial Interaction Models Theory and Planning Models*, ed. Anders Karlquist, Lars Lundqist, Folke Snickers, and Jorgen W. Weibull, 75-96. Amsterdam: North-Holland.

Neill, Helen, David M. Hassenzahl, and Djeto Assane. 2007. "Estimating the Effects of Air Quality: Spatial versus Traditional Hedonic Price Models." *Southern Economic Journal* 73(4): 1088-1111.

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82(1): 34-55.

Sieg, Holger, V. Kerry Smith, H. Spencer Banzhaf, and Randy Walsh. 2004. "Estimating the General Equilibrium Benefits of Large Changes in Spatially Delineated Public Goods." *International Economic Review* 45(4): 1047-77.

Smith, V. Kerry and Ju-chin Huang. 1995. "Can Markets Value Air Quality? A Meta-Analysis of Hedonic Property Value Models." *Journal of Political Economy* 103(1): 209-27.

Smith, V. Kerry, Holger Sieg, H. Spencer Banzhaf and Randy Walsh. 2004. "General Equilibrium Benefits for Environmental Improvements: Projected Ozone Reductions under EPA's Prospective Analysis for the Los Angeles Air Basin." *Journal of Environmental Economics and Management* 47(3): 559-84.

Stadelmann, David, and Steve Billon. 2012. "Capitalisation of Fiscal Variables and Land Scarcity." *Urban Studies* 49(7): 1571-1594.

Takeuchi, Akie, Maureen Cropper, and Antonio Bento. 2008. "Measuring the Welfare Effects of Slum Improvement Programs: The Case of Mumbai." *Journal of Urban Economics* 64(1): 65-84.

Tra, Constant. 2007. "Evaluating the Equilibrium Welfare Impacts of the 1990 Clean Air Act Amendments in the Los Angeles Area." Ph.D. thesis, University of Maryland, College Park, Maryland.

Tra, Constant. 2010. "A Discrete Choice Equilibrium Approach to Valuing Large Environmental Changes." *Journal of Public Economics* 94(1-2): 183-196.

Table 1: High Ozone 8-hour Days in the Las Vegas Metropolitan Area (2003-2010)

	2003	2004	2005	2006	2007	2008	2009	2010
High Days	10	4	27	25	17	9	3	1
Peak Value (parts per billion)	88 ppb	79 ppb	105 ppb	94 ppb	90 ppb	83 ppb	81 ppb	82 ppb

Source: Clark county Department of Air Quality and Environmental Management.
http://ccaqapps5m.co.clark.nv.us/cgi-bin/ozone_summary.pl

Table 2: Full Sample of Houses vs. Estimation Sample

	Full Sample (31,364 observations)			Estimation Sample (12,990 observations)		
	Mean	Std. Dev.	Median	Mean	Std. Dev.	Median
Sale price	355,410	173,471	320,000	357,731	146,125	318,758
Bedrooms	3.3	0.8	3	3.3	0.8	3
Bathrooms	2.6	0.7	3	2.6	0.7	3
Lot size (Acres)	0.14	0.1	0.13	0.14	0.1	0.13
Building size (Feet^2)	1,954	760	1,769	1,933	749	1,748
Age	8.2	12.6	2	10.9	13.4	6

Table 3: Parameter Estimates for the Sorting Model

First-Stage MLE

	Coef.	T-stat
Log(household income – rental price)	9.01	123.91
Ozone air pollution * Household income	-3.93	-4.02
4th grade students proficient in math * Income	0.20	4.39
Log-Likelihood	-57163	
McFadden pseudo-R^2	0.22	

Second-Stage OLS [i]

	Coef.	T-stat	Coef.	T-stat
Intercept	-3.04	-25.79	-3.03	-24.65
Bedrooms	0.21	19.18	0.24	22.79
Pool	0.40	18.49	0.38	18.43
Age	-0.02	-33.14	-0.02	-22.64
Lot size	4.85	24.62	4.87	24.33
Condo (vs. Single-family dwelling)	-0.32	-11.18	-0.28	-10.66
4th grade students proficient in math	1.77	34.44	1.07	17.20
Bathrooms	0.53	37.27	0.45	31.60
Fireplace	0.39	24.48	0.39	25.20
Census tract proportion of minorities	-	-	-0.27	-3.74
Census tract median income	-	-	5.0E-06	7.37
Zip code population density in 2006	-	-	-3.8E-05	-7.96
Zip code housing density 2006	-	-	8.8E-05	6.81
Zip code population growth 2004-06	-	-	0.02	8.56
Zip code housing growth 2004-06	-	-	-0.07	-8.49
Zip code employment density 2006	-	-	-4.0E-06	-1.67
Zip code business density 2006	-	-	2.9E-04	4.77
Zip code employment growth 2004-06	-	-	0.02	2.48
Zip code business growth 04-06	-	-	0.09	5.02
Ozone air pollution	-7.83	-6.38	-8.02	-6.86
Distance to closest park	-	-	0.07	14.90
Distance to closest park * Park acreage	-	-	4.9E-04	5.41
R^2	0.72		0.75	
Implied MWTP for air quality($/year) [ii]	103		104	

[i] Second-stage standard errors are computed using White's robust covariance matrix.
[ii] Constant 2006 dollars. MWTP for a 1 percent reduction in the mean 2006 ozone air pollution level.

Table 4: Benefits of Meeting the 2008 Ozone Daily National Standard in Las Vegas Valley ($/year)

			Partial equilibrium welfare measures			General equilibrium welfare measures			
	Mean household income in 2006 I	Ozone avg. daily maximum level in 2006 II	Mean WTP III	WTP Bottom income quartile IV	WTP Top income quartile V	% change in housing price [i] VI	Mean WTP VII	WTP Bottom income quartile VIII	WTP Top income quartile IX
Las Vegas Valley	122,000	0.083	1,632	348	4,632	-0.08%	1,644	360	4,656
By Neighborhood Ozone									
Bottom 10 % (cleanest)	132,000	0.075	2,076	348	5,808	-2.02%	2,088	360	5,844
Top 10 % (dirtiest)	116,000	0.088	1,320	360	3,456	1.29%	1,332	372	3,480

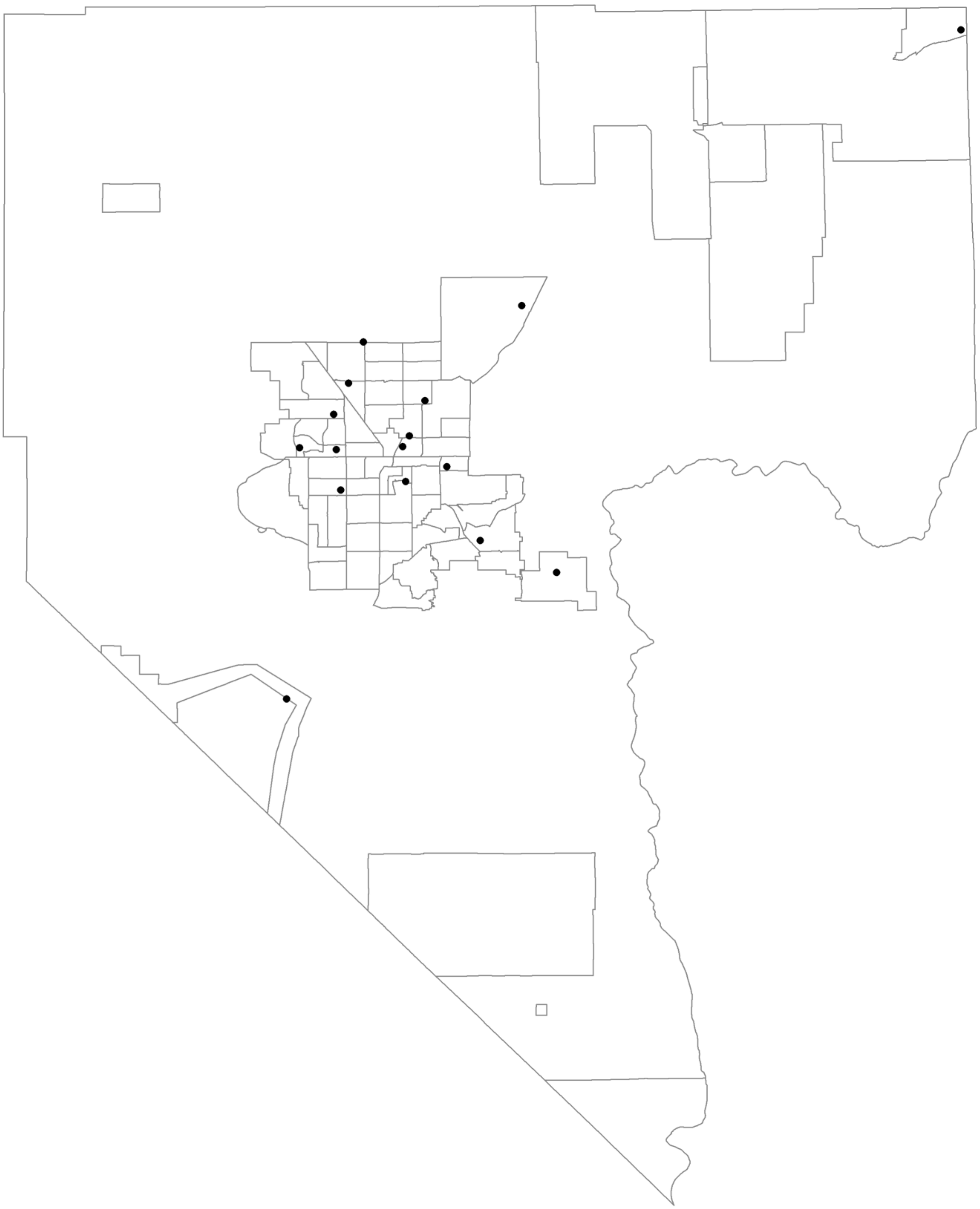
This Table shows the benefits of bringing the 2006 ozone levels, in the Las Vegas metropolitan area, in compliance with the 2008 daily national ozone standard. All WTP values are in 2006 constant dollars. [i] Percent changes in housing prices are computed from the difference between the 2006 benchmark equilibrium and the simulated counterfactual equilibrium.

Table 5: Distribution of Benefits across Incorporated Areas ($/year)

	Mean household income in 2006	Ozone avg. daily maximum level in 2006	Mean WTP for achieving 2008 daily standard (0.08 ppm)
Las Vegas Valley	122,000	0.083	1,644
Henderson, City	136,000	0.080	2,124
Boulder City	135,000	0.079	1,752
Las Vegas, City	123,000	0.084	1,656
North Las Vegas, City	100,000	0.085	1,020

This Table shows the general equilibrium benefits of bringing the 2006 ozone levels, in the Las Vegas metropolitan area, in compliance with the 2008 daily national ozone standard. All WTP values are in 2006 constant dollars.

Figure 1: Clark County Air Pollution Monitors and 2006 Zip Code Boundaries



Footnotes

[1] The population of Clark County was about 800,000 in 2000, which would amount to only 8 Census Public-Use Microdata Areas (PUMA). In comparison, the Los Angeles metropolitan area had 104 PUMA in 2000.

[2] Klaiber and Phaneuf (2010) attempt to address this issue by supplementing housing transactions data with approximated household characteristics based on census block and census block-group averages. Their model is used to estimate heterogeneous preferences for open space in the Twin Cities.

[3] The data are available at http://www.ffiec.gov/hmda/default.htm.

[4] It should be noted that given the total area of roughly 8,000 square-miles the concentration of air quality monitors in Clark is similar to other metropolitan areas. In comparison, the greater Los Angeles area has 50 air quality monitors scattered over an area of 34,000 square-miles.

[5] For a large urban area like Los Angeles, Tra (2010) addresses this issue by incorporating the household's employment location into the indirect utility.

[6] It should also be noted that the hedonic framework assumes that the housing market is in equilibrium as Rosen (1974) clearly states in the theoretical setup of the hedonic model. Assumption (2) essentially takes as given, the existence of a hedonic equilibrium in the housing market.

[7] Note: The H^{th} alternative constant is set to zero.

[8] At first glance it would appear that one is attempting to estimate more than 12,990 parameters from a dataset of 12,990 observations. This is a misconception and is not correct. One should

note that the attribute matrix that is used by the multinomial logit is of size N*101, where N is the number of households in the sample (12,990) and 101 is the number of housing products in each household's choice set.

[9] We should note that this would not be the case if housing prices were also housing attributes in the second-stage estimation. In that, case an instrument for housing prices would be needed. This model does not treat housing prices as attributes of residential locations. Rather, housing prices enter the first-stage estimation as part of the household's budget constraint.

[10] Our MWTP formula is consistent with the formulae for MWTP in discrete choice models discussed in Hanemman (1983).

[11] While we focus in this study on the benefits of air quality regulations, one cannot ignore the potential costs of imposing these regulations. If these costs are not equally shared across the area we may suppose that they would also influence house prices and thereby reduce the potential benefits. However this is not the case in this application since the regulatory costs are born by Clark County and hence are shared equally across the valley. We anticipate this to be the case in most small urban areas.

[12] See Tra (2010) for a detailed discussion of approaches to valuing amenity changes.