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The Effects of Locational Point Representation of Apartment Complexes on Hedonic Valuation of Air Quality

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공동주택 위치표현 방법이 대기질의 한계잠재가격 측정에 미치는 영향

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Abstract : The marginal implicit price of air quality can be measured by taking a partial derivative of hedonic price function (HPF) with respect to the level of air quality. It has been pointed out that the size of the marginal implicit price varies with the use of different function forms, different estimation methods, and the different ways of measuring air quality level in estimating HPF. In addition to these factors, this study shows theoretically and empirically the way housing properties are represented on a digital map could differentiate the size of marginal implicit price of air quality when GIS is used to measure location attributes of the housing properties in the Korean apartment market. Furthermore, this study shows that the degree of difference in the marginal implicit price due to the manner in which housing properties are represented on a digital map can be larger than the degree of difference in the marginal implicit price due to using different function forms and estimation methods. The major implication from the results of this study is that one should carefully try diverse ways of representing housing properties in the Korean apartment market on a digital map in the process of estimating HPF, as he or she usually tries diverse function forms and estimation methods, to see if the value of the marginal implicit price of air quality varies substantially.

Key Words : marginal implicit price, air quality, GIS

요약 : 본 연구에서는 점 객체 (Point Object)를 이용하여 수치지도상에 아파트 단지의 위치를 표현하는 다양한 방법에 따라 GIS와 헤도닉 함수를 이용한 대기질의 한계잠재가격의 추정치가 달라지는 문제점을 검토하였다. 본 연구에서 다루어진 수치지도상에 아파트 단지의 위치를 표현방법은 아파트 단지의 중심점을 이용하는 방법, 중심점에서 수평으로 우측 100미터 떨어진 점을 이용하는 방법, 중심점에서 수평으로 우측 50미터 떨어진 점을 이용하는 방법, 중심점에서 수평으로 좌측 100 미터 떨어진 점을 이용하는 방법 등이다. 4가지 방법은 개별 아파트가 아닌 아파트 단지별로 아파트의 가격과 속성이 공개되는 현재와 같은 상황에서 아파트 단지를 대표할 수 있는 점들로 가정되었다. 4개의 방법을 통해 각기 다른 지점에 표현된 수치지도상의 아파트 위치와 GIS를 이용하여 헤도닉 함수추정에 필수적인 위치변수가 측정되었다. 그리고 측정된 위치변수, 아파트의 물리적 속성을 나타내주는 변수, 아파트 위치에서의 미세먼지 (PM10) 수준을 나타내는 변수를 포함한 4개의 헤도닉 함수가 추정되었다. 또한 추정결과를 이용하여 미세먼지의 한계잠재가격이 추정되어 그 크기가 상호 비교되었다. 추정된 4개 함수간에 존재하는 차이를 중심점을 이용했을 경우의 얻어진 한계잠재가격을 기준으로 상호비교할 경우 그 크기의 차이는 3.33%에서 11.91% 정도임이 드러났다. 이는 중심점을 이용했을 경우 얻어진 데이터에 다른 함수식이나 다른 추정방법을 적용하였을 경우에 얻어지는 한계잠재가격들 간의 차이보다 크거나 유사한 것이다. 본 연구의 시사점은 GIS와 헤도닉 함수를 이용한 대기질의 한계잠재가격의 추정시 수치지도상의 아파트단지 위치표현방법이 적지 않은 영향을 미치기 때문에 다양한 위치표현 방법을 시도하여 분석결과가 민감하게 변하는 가를 주의 깊게 분석해야 한다는 점이다.

주요어 : 한계잠재가격, 대기질, 지리정보시스템

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1. Introduction

The marginal implicit price of air quality can be measured by taking a partial derivative of hedonic price function (HPF) with respect to the level of air quality. It has been pointed out that the size of the marginal implicit price varies with the use of different function forms, different estimation methods, and different ways of measuring the attribute in estimating HPF(Graves *et al.*, 1988; Kim, Phipps, and Anselin, 2003).

In addition to these factors, this study shows theoretically and empirically the manner in which housing properties are represented on a digital map could differentiate the size of the marginal implicit price of air quality when GIS is used to measure location attributes of the housing properties in the Korean apartment market.

The remainder of this paper is organized as follows. In the next section the theoretical issue underlying the this study is described. Section three contains a detailed description of the research design, study area, and data used in the study. Section four is concerned with the empirical results. Concluding remarks are offered in the final section.

2. Related Theories and Studies

1) Hedonic Price Function

HPF treats a property as a composite good containing diverse component attributes, ranging from lot size to access to CBD (Rosen, 1974). HPF shows a statistical relationship between property value and component attributes. The relationship can be described as follows (Can, 1992):

$$P(H)=f(h_1, h_2, \cdots\cdots, h_k) \qquad (1)$$

where P represents property value; H represents a set of attributes; $h_1,.,h_k$ represents individual attribute. Mainly, HPF is estimated to value environmental goods.

The price of individual attribute such as h_k in H, MIP_k ($\partial P(H)/\partial h_k$) is called as the marginal implicit price of that individual attribute. The marginal implicit price indicates the market premium to be paid by a household to consume one more level of the attribute. Small (1975) and Freeman (1993) show that the marginal implicit prices of any attribute such as air quality at the residential sites can be used to measure the marginal economic benefit and loss for small changes in those attributes.

In the specification of HPF, the value of a property is related with four major classes of attributes. The first group includes physical attributes such as lot size and number of rooms. The second group includes neighborhood attributes such as neighborhood income, racial distribution of the neighborhood, etc. The third group includes location attributes such as distance to CBD, distance to greenbelt, etc. The fourth group includes environmental attributes such as air quality level of a location. Therefore, in the econometric aspect the general form of HPF can be described as:

$$P(H)=f(S, N, L, E, \beta, \delta, \gamma, \theta)+e \qquad (2)$$

where P is a vector of observed property values; S is a vector of structural attributes; N is a vector of neighborhood attributes; L is a vector of location attributes; E is a vector of environmental attributes; β, δ, γ, and θ are associated parameter vectors; and e is a vector of random error terms.

2) Location Variables and HPF

The location variables which represent location attributes of housing properties in HPF are proxy variables because they are used as indicator variables representing something that can not be directly measured. For example, a location variable, "distance to a park" is a proxy variable used to measure amenities and disamenities from the access to a park, which are not directly observed.

A typical location variable, X_i can be represented as (3), a variable with measurement error because this is a proxy variable.

$$X_i = x_i + u, \qquad (3)$$

where X_i is ith location variable; x_i represents true amenities and disamenities; and u is measurement error.

If this location variable is used as an explanatory variable with other non-location variables in multiple regression for HPF, the estimated coefficients of all the variables are biased. This point can be explained by using a HPF with two explanatory variables as defined in (4) where X_1 is a location variable and X_2 is a non-location variable. If we apply ordinary least square to (4) with large samples, we have bias in $\hat{\beta}_1$ and $\hat{\beta}_1$ following the forms of (5) and (6).[1)]

$$Y = \beta_1 X_1 + \beta_2 X_2 + w,\ X_1 = x_1 + u,\ X_2 = x_2, \text{ where } w = e - \beta_1 u,\ \mathrm{cov}(u, e) = \mathrm{cov}(u, x_1) = \mathrm{cov}(u, x_2) = \mathrm{cov}(u, Y) = 0, \text{ and } X_1 \text{ and } X_2 \text{ are normalized to have a unit variance.} \qquad (4)$$

$$\text{bias in } \hat{\beta}_1 : \hat{\beta}_1 - \beta_1 = \frac{\beta_1 \lambda}{1 - \rho^2}, \text{ where } = \lambda \frac{\delta_u^2}{var(X_1)}, \quad \rho = \mathrm{cov}(X_1, X_2),\ \delta_u^2 = var(u) \qquad (5)$$

$$\text{bias in } \hat{\beta}_2 : \hat{\beta}_2 - \beta_2 = \frac{\beta_1 \lambda \rho}{1 - \rho^2} = \rho(\hat{\beta}_1 - \beta_1) \qquad (6)$$

As shown in (5) and (6), the bias of the location variable depends on λ and ρ while the bias of the non-location variable depends on the form of the bias in the location variable ($\hat{\beta}_1 - \beta_1$) and ρ. In empirical research studies, it is generally assumed that the size of λ is relatively very small and, thus, the degree of bias in $\hat{\beta}_1 - \hat{\beta}_2$ is negligible.

3) Locations of Apartment Complexes on a Digital Map and Marginal Implicit Price of Air Quality

From the mid of 1990s, Geographic Information Systems (GIS) have been extensively used to measure the location variables in estimating HPF for the Korean apartment market. This is because digital maps with diverse geographic information and scales have been available to the public since then. The first step to use GIS coupled with digital map in estimating HPF for the Korean apartment market is to represent the locations of the apartment complexes with point features on digital map such the center point on Fig. 1. After this is done, GIS can be used to measure various types of the location variables with reference to the point features.

One problem with this step is that there are too many ways to represent an apartment complex with a point feature on a digital map. This means that any point features can represent an apartment complex on digital map as long as the point features are contained within the area occupied by the apartment complex. The fact that many point features can be used to represent an apartment complex causes a serious problem in estimating HPF for the Korean apartment market with GIS and digital map. The problem is that even if we use a data set including the same apartment complexes to estimate a HPF, we may get different estimated coefficients for all the apartment attributes considered according to the way the apartment complexes are represented on digital map with point features. This is because the size of location variables measured from the point

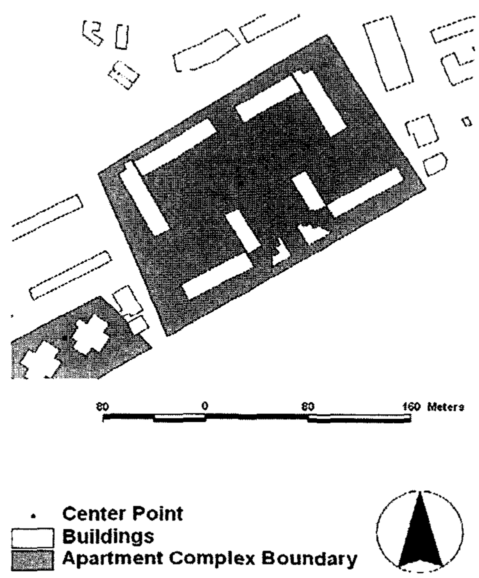

Fig.1. An Apartment Complex Example

features will be differentiated according to the way how apartment complexes are represented on a digital map and, consequently the difference affects the size of all the coefficients in HPF including the coefficient of air quality, which determines the size of the marginal implicit price of air quality.

Using econometric terms used in (3), this is to say that the error term, u in (3), varies with the way apartment complexes are represented on a digital map with point features. If we have n ways of representing apartment complexes on a digital map, then, we actually have n types of measurement error(u^1, ……, u^N) for single location attribute (X_1) such as (7).

$$X_1^1 = x_1 + u^1, \cdots\cdots, X_1^N = x_1 + u^N \qquad (7)$$

If this is the case, in fact, we have total λn number of s (λ^1, ……, λ^N) and, consequently, total n number of different $\hat{\beta}_2$s ($\hat{\beta}_2^1$, ……, $\hat{\beta}_2^N$) which may represent the differentiated coefficients for air quality variable in HPF. This result implies that if we use different ways of representing apartment complexes on a digital map, we may have different estimates for the coefficient of air quality variable from a HPF.

4) Related Studies

Thus far, Kim, Phipps, and Anselin (2003), Choi and Sim (2002), and Kwak, Lee and Chun (1996) have reported marginal implicit prices of various types of air pollutants by using housing market data of Korea and HPF.

Kim, Phipps, and Anselin (2003) used the survey data of the Seoul housing market in 1993 and spatial econometric methods to estimate the marginal implicit price of SO_2. They found that the marginal implicit price for a 4% improvement in SO_2 concentration level is about $2,300. They also found that the size of the marginal implicit price varies with estimation methods used.

By using Seoul's apartment market data in 2000, Choi and Sim (2002) reported that the monthly benefit of a 10% improvement in SO_2 (O_2) from Seoul's mean SO_2 (O_2) level is 36,000 (39,000) won. They used Box-Cox transformation to find optimal function form of HPF.

Kwak, Lee and Chun (1996) estimated the marginal implicit price of TSP level in Seoul, Korea. They used the data on housing price and housing characteristics from the Survey on Housing Finance and Market (1991) by the Korea Research Institute for Human Settlement. They reported that the average benefit of a 5% reduction in TSP from the current level is 2,199,208 won (US $2,749). They also used Box-Cox transformation to find a optimal function form of HPF.

Aside from Choi and Sim (2002), no study uses the location of the individual housing unit or apartment complex as a reference point to measure location variables.

In case of Kim, Phipps, and Anselin (2003), their data includes respondent's subjective judgement about accessibility to major destinations such as schools, hospitals, and parks from his or her house. Therefore there exists no need for them to know the location of the individual housing unit. Kwak, Lee, and Chun (1996) used the location of the main administrative building of the Gu government where the housing units for analysis are located to measure location variables such as distance to CBD. In contrast to other studies, Choi and Sim (2002) measured location variables such as distance to the subway station from an individual apartment complex by using Web-GIS provided by *Boo-dong-san* Bank, a major commercial real estate information provider.

This brief review shows that the previous studies on the marginal implicit price of air quality in Korean housing market employed diverse estimation methods and Box-Cox transformation in their studies because the size of the marginal implicit price varies according to estimation methods and function forms used. However, no one paid attention to the possibility that the size of the marginal implicit price of air quality varies according to the way housing properties are represented with point features on a digital map even though one study actually used GIS to measure location variables.

3. Research Objective and Design, Study Area, and Data

1) Research Objective and Design

The objective of this paper is to show theoretically and empirically the way housing properties are represented on a digital map could differentiate the size of the marginal implicit price of air quality when GIS is used to measure location attributes of the housing properties in the Korean apartment market. The theoretical aspect of the objective is fulfilled in section 2.

To achieve the empirical aspect of the objective, this study addresses two research questions. The first question is how much difference exists among the size of the marginal implicit prices of air quality calculated through different ways of representing apartment complexes on a digital map. The second question is how serious is the difference if it exists, when compared with the difference that might result from using different function forms or different estimation methods.

To deal with the first question, this study considers four methods to represent apartment complexes on a digital map with point features as indicated in Fig. 2.[2)] The first is to use the center point of a polygon that represents the area of an apartment complex. The second is to use the point located horizontally to the right-hand side of the center point and 100 meters apart (RHS point). The third is to use the point located horizontally to the right-hand side of the center point and 50 meters apart (RHS50 point). The fourth is to use the point located horizontally to the left-hand side of the center point and 100 meters apart (LHS point).[3)]

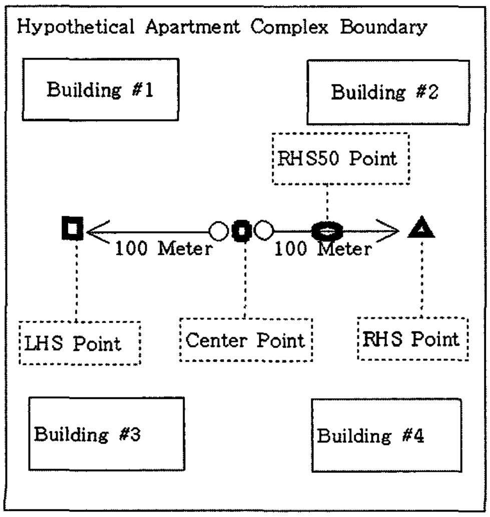

Fig. 2. Four Types of Point Features

With four methods explained, this study estimates the four following HPF specifications such as (8), (9), (10), and (11). Then, this study compares the marginal implicit prices of air quality from the four specifications. These four specifications differ with each other in that the location variables included in each specification are measured from the point features generated by one the four methods. In other words, (8) includes the location variables measured from the center point while (9), (10) and (11) include the location variables measured from RHS, RHS50 and LHS points respectively.

Center Point Model

$$\begin{aligned}\ln(MP) = {} & \alpha^0 + \alpha^1 PYOUNG + \alpha^2 THH + \alpha^3 AGE + \\ & \alpha^4 AGESQ + \alpha^5 DSUBC + \\ & \alpha^6 DGANGC + \alpha^7 DYOUNGC + \\ & \alpha^8 \%PARKC + \alpha^9 PM_{10+} e\end{aligned} \quad (8)$$

RHS Point Model

$$\begin{aligned}\ln(MP) = {} & \beta^0 + \beta^1 PYOUNG + \beta^2 THH + \beta^3 AGE + \\ & \beta^4 AGESQ + \beta^5 DSUBR + \\ & \beta^6 DGANGR + \beta^7 DYOUNGR + \\ & \beta^8 \%PARKR + \beta^9 PM_{10+} e\end{aligned} \quad (9)$$

RHS50 Point Model

$$\begin{aligned}\ln(MP) = {} & \gamma^0 + \gamma^1 PYOUNG + \gamma^2 THH + \gamma^3 AGE + \\ & \gamma^4 AGESQ + \gamma^5 DSUBR50 + \\ & \gamma^6 DGANGR50 + \gamma^7 DYOUNGR50 + \\ & \gamma^8 \%PARKR50 + \gamma^9 PM_{10+} e\end{aligned} \quad (10)$$

LHS Point Model

$$\begin{aligned}\ln(MP) = {} & \theta^0 + \theta^1 PYOUNG + \theta^2 THH + \theta^3 AGE + \\ & \theta^4 AGESQ + \theta^5 DSUBC + \\ & \theta^6 DGANGL + \theta^7 DYOUNGL + \\ & \theta^8 \%PARKL + \theta^9 PM_{10+} e\end{aligned} \quad (11)$$

The definitions of variables used in the equations are provided in Table 1. MP represents the average price of the apartment units with the same floor space in an apartment complex. The logarithm of MP is used as a dependent variable. Among the independent variables used, PYOUNG, THH, AGE, and AGESQ represent physical attributes of individual apartment housing units. The variable, AGE is inserted into (8), (9), (10) and (11) as a quadratic form to capture increasing or decreasing effects of AGE on apartment prices.

The variables, DSUBC, DSUBR, DSUBR50, DSUBL, DGANGC, DGANGR, DGANGR50, DGANGL, DYOUNGC, DYOUNGR, DYOUNGR50 DYOUNGL, PARKC, PARKR, PARKR50 and PARKL are location variables measured from the four point features that represent an apartment complex in slightly different ways as explained. The variable, PM_{10} is the exclusive air quality variable considered.

To deal with the second question, this study estimates the specification (8) with different function forms (e.g., linear and double log) as indicated in (12) and (13). (12) is the linear model based on the center point and (13) is the double log model based on the center point. After estimating (12) and (13), this study compares the marginal implicit prices of air quality from two models with that of (8).

Linear Center Point Model

$$MP = \alpha^0 + \alpha^1 PYOUNG + \alpha^2 THH + \alpha^3 AGE + \alpha^4 AGESQ + \alpha^5 DSUBC + \alpha^6 DGANGC + \alpha^7 DYOUNGC + \alpha^8 \%PARKC + \alpha^{9L} PM_{10} + e \quad (12)$$

Double Log Center Point Model

$$\ln(MP) = \alpha^0 + \alpha^1 PYOUNG + \alpha^2 THH + \alpha^3 AGE + \alpha^4 AGESQ + \alpha^5 DSUBC + \alpha^6 DGANGC + \alpha^7 DYOUNGC + \alpha^8 \%PARKC + \alpha^{9D} \ln(PM_{10}) + e \quad (13)$$

Table 1. Variable Definitions

Variable	Definition
MP	Average price of the apartment units with the same floor space in an apartment complex (unit: 10,000 Won: Current price of 2000)
PYOUNG	Floor space (unit: Pyoung)
THH	Total Households in the apartment complex
AGE	2000-Year built
AGESQ	Square of AGE
DSUBC	Distance between Center Point and the nearest subway station (unit: meter)
DSUBR	Distance between the RHS point and the nearest subway station (unit: meter)
DSUBR50	Distance between the RHS50 point and the nearest subway station (unit: meter)
DSUBL	Distance between the LHS point and the nearest subway station (unit: meter)
DGANGC	Distance between the center point and subcenter Kangnam (unit: meter)
DGANGR	Distance between the RHS point and subcenter Kangnam (unit: meter)
DGANGR50	Distance between the RHS50 point and subcenter Kangnam (unit: meter)
DGANGL	Distance between the LHS point and subcenter Kangnam (unit: meter)
DYOUNGC	Distance between the center point and subcenter Youngdungpo (unit: meter)
DYOUNGR	Distance between the RHS point and subcenter Youngdungpo (unit: meter)
DYOUNGR50	Distance between the RHS50 point and subcenter Youngdungpo (unit: meter)
DYOUNGL	Distance between the LHS point and subcenter Youngdungpo (unit: meter)
%PARKC	Percentage of park area within 500 meter from the center point
%PARKR	Percentage of park area within 500 meter from the RHS point
%PARKR50	Percentage of park area within 500 meter from the RHS50 point
%PARKL	Percentage of park area within 500 meter from the LHS point
PM_{10}	Yearly Mean PM10 level measured from the nearest air quality monitoring station (unit=$\mu g/m^3$)

Furthermore, to deal with the second question in terms of estimation methods, this study uses the results from Kim, Phipps, and Anselin (2003) as a reference. In their paper, Kim, Phipps, and Anselin (2003) report that they acquired four different values of marginal implicit prices for SO_2 (Sulfur Dioxide) as reported in Table 6 when they applied four types of estimation methods to the data from the Seoul housing market in 1993. Those estimation methods are Ordinary Least Square (OLS), Maximum Likelihood Estimation (MLE), Spatial 2 Stage Least Square (S-2SLS), and Robust Spatial 2 Stage Least Square (Robuts S-2SLS). This study uses the difference in marginal implicit prices calculated in the third row of Table 6 to see if the difference resulting from four methods of representing apartment complexes on a digital map is smaller or larger than the difference due to using different estimation methods.

2) Study Area and Data

To estimate (8) to (13), apartment sales prices and housing attributes data of Seoul were obtained from *Boo-dong-san* Bank. Among all the apartment complexes that existed as of the year of 2000 in Seoul, this study uses a total of 62 apartment complexes which include a total of 320 observations. Those are so called *Jae-Gae-Bal* apartment complexes, which were redeveloped from single family detached housing units in Seoul's poor neighborhoods. Fig. 3 shows the geographic distribution of the apartment complexes considered in this study. The other data such as land-use GIS map, administrative boundary GIS map, and subway station GIS map, which were used to measure the location variables, were obtained from the Seoul Development Institute. The information about PM10 levels were provided by the city government of Seoul.

The location variables defined in Table 1 were measured based on the following steps. First, the latitude and longitude coordinates of the center points of the 62 apartment complexes were obtained by using address information[4)] and Almap software.[5)] Second, the latitude and longitude coordinates of the center points were converted to TM coordinates. Third, the TM coordinates were used to create point features by using shape file format and ArcView.

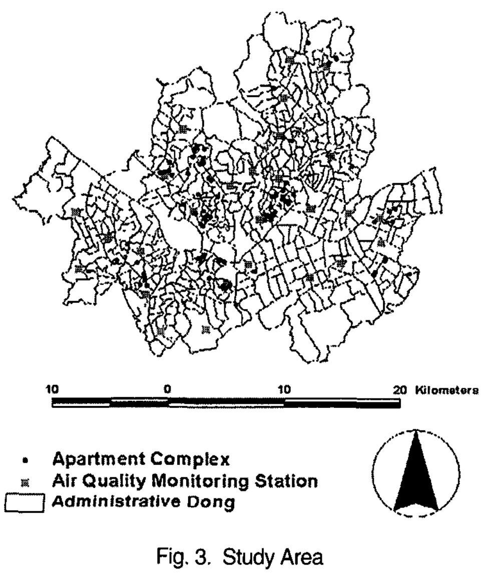

Fig. 3. Study Area

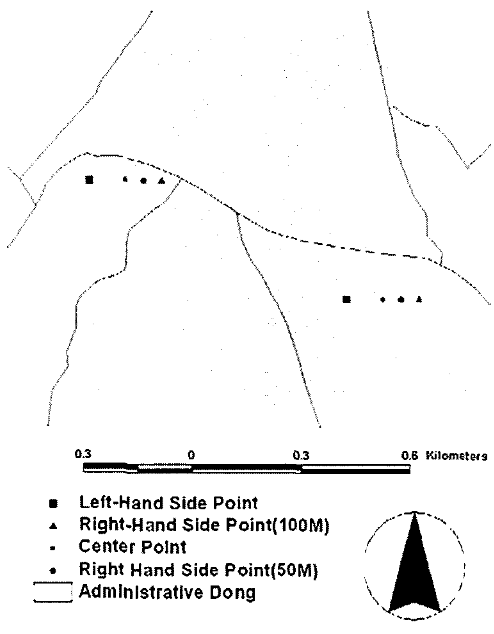

Fig. 4. Four Types of Point Features For Apartment Complexes

Table 2. Summary Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
MP	320	20668.98	8710.938	5825	53500
PYOUNG	320	32.54063	8.608422	13	56
THH	320	813.1063	503.3959	75	2399
AGE	320	6.73125	4.585273	0	15
AGESQ	320	66.26875	65.1245	0	225
DSUBC	320	514.7233	280.271	99.935	1490.327
DSUBR	320	517.2044	292.3402	10.642	1486.505
DSUBR50	320	515.1118	285.0299	50.499	1453.996
DSUBL	320	518.5067	279.4148	131.546	1578.168
DGANGC	320	9684.334	3898.656	4416.966	19169.65
DGANGR	320	9635.539	3882.691	4340.033	19070.07
DGANGR50	320	9659.88	3890.577	4378.383	19119.86
DGANGL	320	9733.577	3915.389	4494.808	19269.23
DYOUNGC	320	10314.75	5879.922	1940.691	22802.99
DYOUNGR	320	10378.12	5900.758	1850.985	22870.01
DYOUNG50	320	10346.36	5890.343	1895.709	22836.47
DYOUNGL	320	10251.93	5859.074	2031.358	22736.21
%PARKC	320	2.311818	2.70529	0	13.82883
%PARKR	320	2.40166	2.945111	0	13.05656
%PARKR50	320	2.349004	2.803659	0	13.55631
%PARKL	320	2.22769	2.618997	0	13.90611
PM_{10}	269	59.92349	10.1935	44.75	90.167

Fourth, the newly generated shape file was used to generate RHS, RHS50 and LHS points as shown in Fig. 4.[6] Fifth, all the necessary location variables were measured from the point features generated.

Table 2 shows the summary statistics of the variables used to estimate (8) to (13). The last row of Table 3 reports the summary statistics for PM10 variable.[7] In this row, statistics for only 269 observations are reported. This is because only 21 monitoring stations kept recordings of PM10 in 2000 and 60 observations close to 6 monitoring stations which didn' t record PM10 level were omitted.[8]

4. Regression Results and Marginal Implicit Prices

Table 3 and Table 4 present estimation results of (8) to (11). Initial ordinary least square estimation of (8) to (11) specifications showed the existence of heteroskedasticity and therefore, White's heteroskedasticity-corrected estimates (White, 1980) are reported in Table 4 and Table 5. As shown in the Tables, most of the variables are significant at the 1% level except DSUBC and DSUBL, which are significant at the 5% level. The R-square of the functions are around 89% which indicates four specifications explain 89% of the variation in apartment sales prices. In the semi-log specifications like (8) to (11), the coefficient represents a percentage change of the dependent variable for each unit change in the independent variables. For example, the coefficient for DSUBC means that a unit (one meter) increase in subway station accessibility increases the sales prices of apartment by 0.008%.

By using the results from the four different specifications, the marginal implicit prices of PM_{10} can be calculated. Marginal implicit price is the price of the individual housing attributes obtained from the first partial derivatives of the HPF with respect to each

Table 3. Regression Results I

	Center Point Model			RHS Point Model		
	Coef.	t		Coef.	t	
PYOUNG	0.04038	37.21500	***	0.04048	37.43500	***
THH	0.00008	4.76800	***	0.00008	4.68500	***
AGE	-0.05971	-5.05000	***	-0.06037	-8.37400	***
AGESQ	0.00270	5.06100	***	0.00270	5.04600	***
DSUBC/DSUNR	-0.00008	-2.57300	**	-0.00007	-2.75100	***
DGANGC/DGANGR	-0.00002	-9.02400	***	-0.00002	-8.80400	***
DYOUNGC/DYOUNGR	0.00000	-2.74200	***	0.00000	-2.71400	***
%PARKC/%PARKR	0.01409	4.84900	***	0.01375	5.36800	***
PM_{10}	-0.00319	-3.30400	***	-0.00344	-3.55700	***
cons	9.15775	117.100	***	9.17005	119.776	***
R^2	0.89350			0.89390		
F-Value	F(8,259)=289.16			F(8,259)=290.50		

1)***: Significant at 1% level; **: Significant at 5% level; *:Significant at 10% level

Table 4. Regression Results II

	RHS50 Point Model			LHS Point Model		
	Coef.	t		Coef.	t	
PYOUNG	0.04043	37.31400	***	0.04032	37.22700	***
THH	0.00008	4.71900	***	0.00008	4.81700	***
AGE	-0.05964	-8.27800	***	-0.05870	-8.053	***
AGESQ	0.00268	5.01200	***	0.00268	4.95900	***
DSUNR50/DSUBL	-0.00008	-2.64800	***	-0.00008	-2.32300	**
DGANGR50/DGANGL	-0.00002	-8.88400	***	-0.00002	-9.02100	***
DYOUNGR50/DYOUNGL	0.00000	-2.76600	***	0.00000	-3.06600	***
%PARKR50/%PARKL	0.01395	5.02200	***	0.01482	4.86800	***
PM_{10}	-0.0033	-3.40900	***	-0.00285	-2.94900	***
cons	9.16285	118.207	***	9.13672	116.812	***
R^2	0.89360			0.89390		
F-Value	F(8,259)=286.75			F(8,259)=303.24		

1)***: Significant at 1% level; **: Significant at 5% level; *:Significant at 10% level

attribute. Table 5 reports the marginal implicit price of PM_{10}. Looking at the fourth column of Table 5, the difference in marginal implicit prices among (8) to (11) can be seen. The difference between the center point model and RHS point model is 7.78% while the difference is 11.91% between the center point model and LHS point model. The difference between the center point model and RHS50 point model is 3.33%

Table 5 also reports the difference in marginal implicit prices among different function forms such as semi-log (8), linear (12), and double log (13) in case of center point model. The maximum difference exists between the semi-log model and linear model, which is 10.26%. However, this is slightly lower than the 11.91% difference, which exists between the center point model and LHS point model.

For references, Table 6 presents the marginal implicit prices of SO_2 reported by Kim, Phipps, and Anselin (2003). Table 6 reports four different values

Table 5. Marginal Implicit Prices of one unit increase in PM10

Models	Coefficients	Marginal Implicit Prices	Difference
Center Point Model	-0.00319 ($\hat{\alpha}^{9}$)	-66.00845453[1]	
RHS Point Model	-0,00344 ($\hat{\beta}^{9}$)	-71.14676296[1]	7.78[3]
RHS50 Point Model	-0.0033 ($\hat{\gamma}^{9}$)	-68.207634[1]	3.33[3]
LHS Point Model	-0.00285 ($\hat{\theta}^{9}$)	-58.98513512[1]	11.91[3]
Linear Center Point Model	-72.77807 ($\hat{\alpha}^{L9}$)	-72.77807	10.26[3]
Double-Log Center Point Model	-0.19348 ($\hat{\alpha}^{D9}$)	-66.73708413[2]	1.09[3]

1) (Mean Value of MP)*Coefficient

2) (Mean Value of MP/Mean Value of PM10)*Coefficient

3) |(Marginal Implicit Price of Center Point Model - Marginal Implicit Price of Other Model))/(Marginal Implicit Price of Center Point Model)|*100

4) To calculate marginal implicit prices from Semi-Log and Double-Log form, mean value of MP(20668.98) and mean value of PM_{10}(59.92349) were used.

Table 6. Marginal Implicit Prices of SO2

	OLS[1]	MLE[2]	S-2SLS[3]	S-2SLS ROBUST[4]
Marginal Implicit Price (Unit: Million Won)	2433	2408	2391	2333
		1.035)	1.735)	4.115)

1) Ordinary Least Square

2) Maximum Likelihood Estimation

3) Spatial Two Stage Least Square

4) Robust Spatial Two-Stage Least Square

5) |(Marginal Implicit Price of OLS Model - Marginal Implicit Price of Other Model))/(Marginal Implicit Price of OLS Model)|*100

6) The figures in this table represent the marginal benefits per household of permanent 4% improvement in air quality(SO_2)

of marginal implicit prices measured from HPFs estimated with four different estimation methods such as OLS, MLE, spatial 2SLS, and Robust Spatial 2SLS. As one can notice, the differences between marginal implicit prices are relatively small and range between 1.03% and 4.11%.

In sum, these results show that the difference in the marginal implicit prices of air quality due to the way apartment complexes are represented on a digital map can be equal to or more serious than the difference due to using different function forms and estimation methods even with the small difference that exists among the four types of point features used in this study.[9]

5. Conclusions

This study explores how ways of representing apartment complexes on a digital map influence the size of the estimated coefficient of air quality in the HPF for the Korean apartment market. The size of the coefficient is important because this is the basis of calculating the marginal implicit price of air quality, which is critical in evaluating the economic impact of an air pollution abatement project. If the size of the coefficient substantially differs according to the way apartment complexes are represented on a digital map, one should carefully try diverse ways of representing apartment complexes on digital map to reach any conclusions. Otherwise one doesn' t need to spend time consuming attention to this issue.

The results of this study shows that the degree of difference in the marginal implicit price due to the manner in which housing properties are represented on a digital map can be equal to or larger than the difference due to applying different function forms and estimations methods. The major implication from the results of this study is that one should carefully try diverse ways of representing housing properties in Korean apartment market on a digital map in the process of estimating HPF, as he or she usually attempts diverse function forms and estimation methods, to determine if the value of the marginal implicit price of air quality varies substantially.

So far, only a limited number of studies have used GIS and digital maps in estimating the marginal implicit price of air quality. However, more studies will use GIS and digital maps in this area because of the ability of GIS in dealing with large scale spatial data and generating diverse location variables efficiently. Thus, the findings from this study could be used to prevent erroneous conclusions from future studies.

Notes

1) The derivation of (5) and (6) follows Maddala (1993), pp.452-453.
2) The size of area covered with apartment complexes in Seoul is 41.7622 km^2 and there exist 1,883 apartment complexes in Seoul as of 2000 (Seoul Development Institute, 2000; Seoul City Government, 2000). Thus, this study assumes that the size of a typical individual apartment complex in Seoul is 22,179 m^2 (41.7622km^2/1883) and the shape of the apartment complex is a rectangle whose width and length are 200 meters and 110 meters approximately. This assumption is necessary because there is no way to know the size and shape of all the apartment complexes in Seoul.
3) Any point features within the boundary of the typical apartment complex assumed in this study can represent an apartment complex of interest. However, it is almost impossible to consider all of them in this study. Thus, only four of them are considered for convenience. One may consider other point features such as points features located vertically to the center point.
4) Typically, to get the center points of apartment complexes, we can use a GIS software to locate the center points of them automatically if we have polygon features representing them on a digital map. However, this typical method is not used in this study. This is because 1: 5000 scale digital maps available to the public, which are used in this study, don' t include polygon features for them. Instead of creating polygon features for 62 apartment complexes with tedious digitizing works, this study visually finds latitudes and longitudes of the center points by using Almap software.
5) Almap software is a product of ESTSoft. Almap software allows one to find latitude and longitude of a apartment complex by using address information. For details about Almap, please refer to www.altools.com.
6) The average size of the apartment complexes considered is 38,164.38 m^2. This fig. is slightly larger than 22,179 m^2 which is assumed to be the typical size of an apartment complex in Seoul. The smallest size is 3,575 m^2 and the largest size is 139,626 m^2. There is no way to know for sure whether all the RHS, RHS50, and LHS points are located within the apartment complexes in this study because we don't know the exact shape of the apartment complexes. For some cases, RHS and LHS points may be located outside the area covered by the apartment complexes due to small area size. However, even in these cases, most of RHS50 points may be located within the area covered by the apartment complexes. Thus the results of this analysis should be interpreted with these characteristics of the data.
7) For each apartment complex, PM_{10} recording of the closest monitoring station was assigned. The PM_{10} level assigned to each apartment complex didn't vary at all according to the ways of representing apartment complexes on digital map in this study.
8) The city of Seoul has 27 air quality monitoring stations around the city area.
9) Readers should notice that the difference found from RHS50 model is larger than some of the differences resulting from different function forms and estimation methods.

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