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Welfare Impacts of Air Quality Changes in Malaysia: The Hedonic Pricing Approach

Jamal Othman
Redzuan Othman
Norghani Md. Nor

ABSTRACT

This study employs the Hedonic Pricing Model (HPM) to assess the welfare impacts of air quality changes in Malaysia. Results from second stage HPM indicate that households on average derive benefits (welfare gain) of some RM19 for every unit of improvement in air quality index (API) in relation to the baseline API level. This finding provides an insight of the magnitude of welfare gain or loss due to air quality changes.

ABSTRAK

Kajian ini menggunakan teknik Harga Hedonik (HH) untuk menganggar impak kebajikan perubahan kualiti udara di Malaysia. Dapatan dari model HH peringkat kedua menunjukkan secara purata nilai faedah ekonomi yang diperoleh oleh isirumah dari peningkatan setiap unit kualiti udara (diukur oleh indeks pencemaran udara) ialah RM19. Dapatan ini memberi gambaran magnitud perubahan dalam kebajikan pengguna akibat perubahan dalam kualiti udara.

INTRODUCTION

Currently, more than half of Malaysia's population live in urban areas. Along with increasing industrialization and traffic flows, air quality is becoming an increasing welfare concern among urbanites. This study attempts to assess the welfare impacts of air quality changes using the Hedonic Pricing Model (HPM). This study, perhaps the first attempt in Malaysia, is important as it serves to provide the economic values of benefits of air quality improvements or the damages resulting from air quality deterioration. Results will offer an explicit market signal regarding the importance of air quality maintenance or to appraise any ex-ante or ex-post environmental program that affects air quality. Subsequent sections discuss the theoretical framework of the HPM, literature review, model application, model results and policy implications.

THEORETICAL FRAMEWORK OF HEDONIC PRICING MODEL

The HPM is normally used to estimate the economic value of environmental attributes which influences the prices of marketed commodities. The HPM is based on the characteristic theory of value where each marketed commodity is described as a bundle of attributes. The price of the good is determined by its attributes, which include non-marketed environmental amenities. In other words, the environmental amenity under evaluation must be well perceived by buyers as important in affecting prices. For that matter, the HPM is most widely applied on property markets where environmental characteristics such as air quality deterioration, noise pollution, highway congestion, landfill facilities, etc are thought to influence property prices. Another important presumption for the HPM is that competitive market exists for such properties (houses).

Let us consider the decision making process of an individual to purchase a residential property. The utility for that individual is a function of that person's consumption of an aggregate marketed commodity X, a vector of location-specific environmental amenities Z, a vector of structural characteristics of the property (such as size, number of rooms, etc) S and a vector of neighborhood characteristics N (such as quality of schools, accessibility to parks, etc). Given such information, the price of the *i*th property (Ph_i) is a function of the structural (S), neighborhood (N) and the environmental attributes (Z). Mathematically, it is written:

$$Ph_i = Ph(S_i, N_i, Z_i) \qquad [1]$$

The utility of the individual who occupies the house is given by:

$$U = u\,(X, Z_i, S_i, N_i) \qquad [2]$$

Equation 2 is maximized subject to the individual's budget constraint [M]. Assuming the price of X is normalized at 1, the budget constraint can be written as:

$$M = Ph_i + X \text{ or } M - Ph_i - X = 0 \qquad [3]$$

The Lagrange equation (L) for equations [2] and [3] is shown below;

$$L = u(X, Z_i, S_i, N_i) - \lambda\,(M - Ph_i - X) \qquad [4]$$

The first order conditions;

$$\frac{\partial L}{\partial x} = \frac{\partial u}{\partial x} - \lambda = 0 \qquad [5]$$

$$\frac{\partial L}{\partial z_i} = \frac{\partial u}{\partial z_i} - \lambda \frac{\partial Ph_i}{\partial z_i} = 0 \qquad [6]$$

$$\frac{\partial L}{\partial s_i} = \frac{\partial u}{\partial s_i} - \lambda \frac{\partial Ph_i}{\partial z_i} = 0 \qquad [7]$$

$$\frac{\partial L}{\partial n_i} = \frac{\partial u}{\partial n_i} - \lambda \frac{\partial Ph_i}{\partial n_i} = 0 \qquad [8]$$

The combination of environmental quality (Z_i) and good X that maximizes utility is attained when $\mathrm{MRS}_{x,qj}$ is equal to the implicit price of the environmental quality. The implicit price is the amount of money an individual is willing to pay to get an additional unit of environmental quality. This is derived from equation 5 and 6 and can be written;

$$\frac{\partial u / \partial z}{\partial u / \partial x} = \frac{\partial Ph_i}{\partial z_i} \qquad [9]$$

Equation (9) shows an individual maximizes his/her utility by utilizing a combination of X and Z_j until the individual's $\mathrm{MRS}_{x,zj}$ is equal to the implicit price of the environmental characteristics (Z_{ij}) i.e., the additional amount of money that must be paid to move to a higher level of environmental characteristics. If equation (1) is non-linear, the implicit price will be a non-constant.

BENEFITS MEASUREMENT UNDER HPM

Estimation of benefits or welfare impacts under HPM involves two major stages. Firstly, the estimation of Hedonic Price Function, and secondly the estimation of a demand curve for environmental quality.

Stage 1: Estimation of Hedonic Price Function (HPF).

In general, the HPF is written as;

$$P_i = f(S_i, N_i, Z_i) \qquad [10]$$

where;

P_i = Price of ith house or property
S_i = Structural characteristics (I = 1…k) of ith house such as house size and number of rooms
N_i = Neighborhood characteristics (I = 1…m) of ith house such as crime rates and neighborhood quality
Z_i = Environmental characteristics (I = 1…n) of ith house such as air quality and greeneries

This study is especially interested to estimate the economic value of air quality improvements (Z_a). We assume that the HPF is in semi-log form, i.e., log dependent variable function as shown below;

$$\ln P_i = c + \alpha_i S_i + \beta_i N_i + \delta_i Z_i \qquad [11]$$

Estimation of equation [11] gives the relationship between the house price and air quality as shown in Figure 1 below:

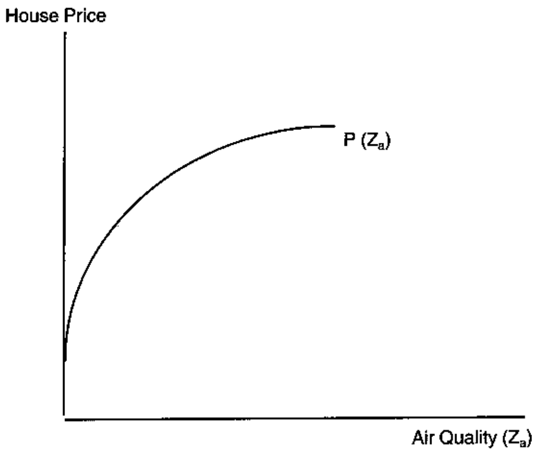

FIGURE 1. House price and air quality

Differentiating equation [11] with respect to the environmental attribute of interest (Z_a) will generate the following marginal implicit price equation;

$$\frac{\partial P}{\partial Z_a} = \delta_a^* \mathrm{Exp}[c + \sum \alpha_i S_i + \sum \beta_i N_i + \sum \delta_i Z_i] = r_{ai} \qquad [12]$$

Diagrammatically, the relationship between marginal implicit price (Equation 12) and air quality is shown in Figure 2. This implicit price function explains the price an individual has to pay in order to obtain an additional unit of improved air quality.

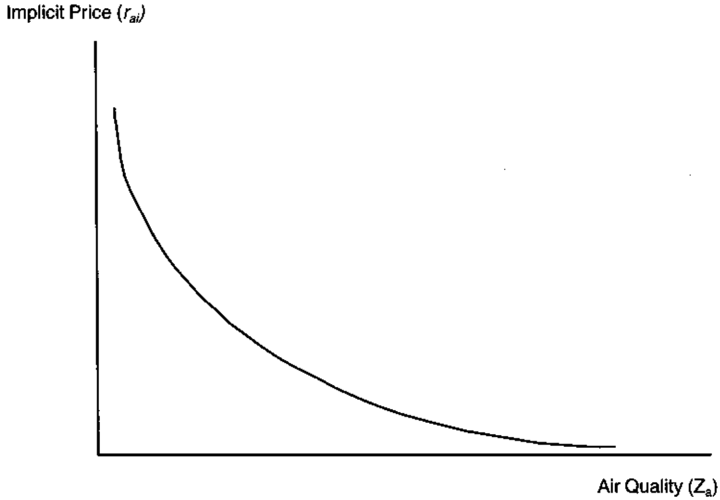

FIGURE 2. Marginal implicit price and air quality

Stage 2: Estimating a Demand Curve

In order to estimate the demand curve for air quality, related information generated in the first stage will be used. In this study, we assume all individuals have similar utility function and the effects of air quality to them are identical. Given this assumption the demand curve can be derived from the implicit price function. If we assume all households' preference and income are identical, the demand for air quality can be estimated by regressing implicit price with air quality and other relevant socioeconomic variables such as income [M_i] and educational level [E_i]. The inverse demand function for air quality in an area within an area can be written as follows;

$$r_{ai} = P(Z_a, M_i, E_i) \quad [13]$$

Regressing equation [13] using non-linear specification, we obtain the following equation;

$$\ln r_{ai} = \alpha_i \ln Q_a + \beta \ln M_i + \delta_i E_i \qquad [14]$$

The inverse demand curve for air quality can be used to estimate the welfare impacts or benefits derived by households when there is a change in air quality level, for example, if there is an improvement in air quality such as reduction in suspended particles. The benefit derived from a change in air quality can be shown in Figure 2. If there is an improvement in air quality from Z_{a1} to Z_{a2}, additional benefits obtained by individual are the area $ABZ_{a2}Z_{a1}$.

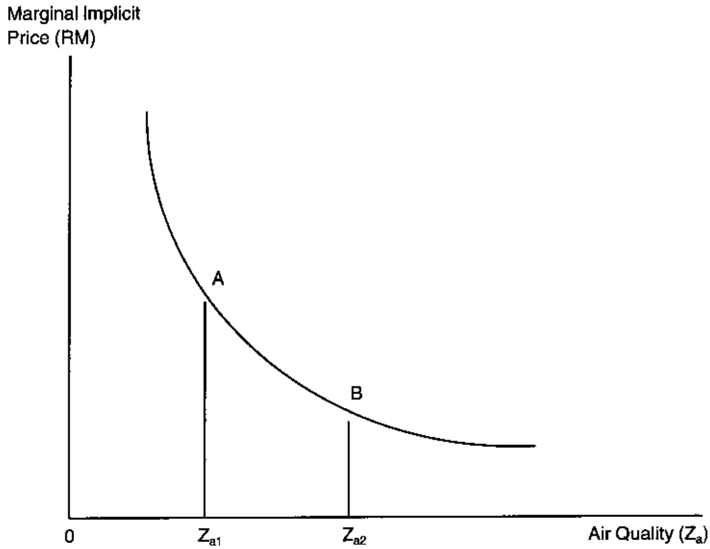

FIGURE 2. Benefits from air quality improvement

LITERATURE REVIEW

Most studies on HPM have been conducted in developed countries such as the US, Europe and Australia. The focus has been on examining the relationship between property prices, structural characteristics and environmental attributes (e.g., air quality, noise pollution, woodland or greeneries), i.e., stage 1 of HPM. Relatively fewer studies have used the HPM to estimate the welfare impacts (stage 2 of HPM) of environmental attribute improvement or degradation. Examples of these studies include Harrison and Rubinfeld (1978), Brookshire, et al. (1982), Nelson (1978), and Garrod and Willis (1992). Brookshire, et al. (1982) in particular found that households in the US were willing to pay $46 for improvement in the level of NO_2 from poor to fair. Virtually, to date, there has been no similar HPM application affecting Malaysian cases.

MODEL APPLICATION

In this study, the HPM was applied to assess the welfare impacts of air quality changes in Malaysia. Data on air pollution index (API) to represent aggregate air quality in Malaysia was obtained from Alam Sekitar Malaysia Sdn Bhd (ASMA). The reference year was 1996. The data were taken from 52 observatory stations throughout Peninsular and Sabah and Sarawak. Year 1996 was taken as the reference year as the needed data for house prices and selected structural attributes were available. Data on house prices, and house attributes such as floor and land area for the reference year were taken from the Property Market Report, 1996. The data represent average prices of newly transacted single and double-storey terrace houses located close to the respective observatory stations. Seventy two residential areas were utilized in the study. Data on average household income for the respective states came from the Economic Report, 1996.

MODEL RESULTS

Table 1 shows the mean statistics for house prices and selected attributes as well as household income. Note that the range of API was within the Good category in the study period, implying air pollution in general was not at all a problem in all the areas covered by the 52 measuring stations. Thus, one can expect that air quality will not have any influence on house prices in Malaysia.

TABLE 1. Mean statistics

	N	Minimum	Maximum	Mean
House price (RM)	74	39000.00	319250.00	91686.57
Average land area (square meter)	74	82.00	248.00	142.48
Average floor area (square meter)	74	48.00	160.00	80.67
Average air pollution index	74	19.00	50.00	34.05
Average household income (RM) (state)	74	1314	4105	2186

RESULTS OF FIRST STAGE REGRESSION

Following Equation 11, the model for the first stage regression was specified:

$$HP_I = f(LNDAREA_i, FLRAREA_i, AIRQLTY_i, INTPTDY_i, SLOPEDY_i)$$

where;

HP_i	=	Average house prices in area i
$LNDAREA_i$	=	Average land area of house in area i
$FLRAREA_i$	=	Average floor area of house in area I
$AIRQLTY_i$	=	Reciprocal of level of Air Pollution Index in area I
$INTPTDY_i$	=	Intercept dummy for main urban areas ("1" for major urban areas and "0" otherwise)
$DAIRQLTY_i$	=	Slope dummy for air quality in major urban areas

Various functional forms were tested, however, log dependent variable specification was found to be best. The intercept and slope dummy (for air quality) were employed to control for differences in demand and supply characteristics between the major urban areas (such as Kuala Lumpur and most cities in the western coast of Peninsula Malaysia) and the lesser developed areas.

Results for the first stage regression are presented in Table 2.

TABLE 2. Results of the first stage HPM regression

	Beta	Std. Error	T	Sig.
(Constant)	9.722	0.253	38.396	.000
LNDAREA	0.00381	0.001	2.978	.004
FLRAREA	0.0115	0.002	5.281	.000
AIRQLTY	0.0002489	0.005	0.052	.959
INTPTDY	1.025	0.292	3.512	.001
DAIRQLTY	–0.02679	0.010	–2.692	.009

$$AR^2 = 0.589, CI = 24, DW = 2.06$$

All coefficients representing the structural characteristics of house were positive and highly significant, reflecting the importance of these attributes in property price determination. A one-unit increase in land

and floor area increases house prices by 0.38 and 1.15 percent, respectively. The coefficient for air quality was of the correct sign but as expected it was not significant. This strongly suggests that air quality in Malaysia, given the range of API used in the study is not a factor in determining the level of house prices.

The results also indicate that house prices in the major urban centers are significantly higher on average by $(\text{Exp}[1.025 - \frac{1}{2} *0.010]-)*100 = 2$ percent relative to non-urban areas. A striking finding is with respect to the negative sign and significancy of the slope dummy for air quality in the major urban areas. As the data for air quality was expressed in terms of reciprocal, the negative sign implies that house prices and air quality deterioration in the major urban areas exhibit a positive correlation. Although this contradicts our expectation, it is justifiable as air quality was always in the Good category range. It also implies that demand pressure was relatively higher in the urban areas relative to rural areas. This further suggests that there is no evidence that air quality has any positive effect on house prices in the country.

The model exhibits quite a good fit of 59 percent and a low level of multicollinearity with a CI of 24.

RESULTS OF SECOND STAGE REGRESSION

Differentiating the first stage regression equation with respect to AIRQLTY (see Equation 12), we obtain an equation representing the marginal implicit price of air quality (IMPRICE). Regressing this equation against AIRQLTY and HHINCME and using a semi-log (ln IMPRICE) specification, the following results are obtained (Table 3):

TABLE 3. Results of the second stage regression

	Beta	Std. Error	T	Sig.
(Constant)	2.390	0.207	11.567	.000
AIRQLTY	–0.0000246	0.004	–0.006	.995
HHINCME	0.000287	0.000	6.109	.000

$$AR^2 = 0.402,\ CI = 15,\ DW = 1.88$$

From the results of the second stage regression, households' willingness to pay for the average air quality was calculated at RM20. The coefficient for AIRQLTY is almost zero, which implies that households' marginal willingness to pay is constant. However, as expected, the coefficient is insignificant. Table 4 depicts the mean statistics for the variable used in the second stage regression – IMPRICE, AIRQLTY and HHINCME (household income).

TABLE 4. Mean statistics

	Mean	Std. Deviation	N
Ln IMPRICE	3.02	2.28	74
AIRQLTY	31.24	8.327	74
HHINCME	2187	742	74

The inverse demand function for AIRQLTY is then estimated from the results of the second stage regression.

WELFARE IMPACTS

The marginal implicit price equation represents the inverse demand curve for air quality if all households have identical utility functions and incomes. Hence, given the estimated inverse demand function, the measure of benefits (welfare gain) or costs (welfare loss) of changes in air quality can be measured as the area below the demand curve between any two points along the marginal implicit price axis. As an illustration, let us suppose air quality would deteriorate from the normal level to API = 50 (maximum API given the sample data – still in moderate category) or its reciprocal 20 ([1/50]*1000), the value of damages or the impacts on welfare per household on average would be:

$$\int_{31}^{20} \text{Exp}[3.017 - 0.0000246 * \text{AIRQLTY}]\, d\mathit{AIRQLTY} = \text{RM}230$$

In other words, households on average were willing to pay a lump sum amount of RM230 to avoid a degradation of air quality from API 32 to 20 (reciprocal of 50) or about RM19 per API unit of air quality decreases. Since marginal implicit price is almost constant, the benefits or welfare impacts can also be estimated by simply multiplying the willingness to pay for the average air quality level by the change in air quality.

CONCLUDING REMARKS

This paper has attempted to estimate the welfare impacts of air quality deterioration or improvements using the HPM. Although general air quality levels were not found to affect house prices significantly, we proceeded to estimate the second stage HPM so as to obtain insights on the lower bound estimates of welfare impacts of air quality changes.

From the generated inverse demand function for air quality, welfare impacts of changes in air quality level, for instance, haze impacts, can be estimated as illustrated by the preceding section. Aggregate values of benefits or damages can be estimated by multiplying the-per household estimates by the total number of affected households. The estimated benefits can then be contrasted to the cost of maintenance or air quality improvements in evaluating (ex-ante or ex-post) the desirability of any budgetary outlay affecting the environment.

Since air quality levels were not significant in affecting house prices, not much confidence can be placed on the magnitude of estimated benefits or damages of changes in air quality levels. Therefore, findings from this study may only provide a general insight of the lower bound estimates of economic benefits (welfare gain) of air quality improvements or damages (welfare loss) due to air quality deterioration.

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Pusat Pengajian Ekonomi
Universiti Kebangsaan Malaysia
43600 UKM Bangi, Selangor D.E.
Malaysia.