Bulgarian Chemical Communications, Special Edition H, (pp. 47 – 52) 2017

Evaluating air quality through aerial demand function and an application evaluating air quality

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Received June 26, 2017; Revised July 20, 2017

This paper primarily explores a methodological framework to analyze demand of an omnipresent public good, the concrete instantiation of setting up an aerial demand function to describe its application of influencing on air quality change, for the purpose of compensating the air pollution impairing environmental quality and human health negatively and chronically, and conducing to avoiding cognitive complexity of air quality variety. Bottom-up approach of acquiring individual state preference sampling, and top-down technique of attaining the related air quality variables' sampling, are jointly adopted to support the empirical survey. Due to the former data, contingent valuation method is used to calculate Hicks' consumer surplus; owing to the latter data and the foregoing result, air demand functions is computed to explain the predictor variables' marginal effects. The findings are that the decreased 10 units AQI to improve air quality leads to the average individual willingness to pay in 2 to 4 Yuan, and PM10 concentration engenders the larger effect on human health.

Keywords: Air quality index (AQI); air demand function (ADF); contingent valuation method (CVM); air economic value; marginal effect

AIMS AND BACKGROUND

The air pollution in urban areas has been chronically negatively impaired human health. At the moment, particulate matter (PM), volatile organic compound (VOC) and aerosol pollutants are widely discussed. Simultaneously, TSP (Total Suspended Particulate, of diameter greater than 10 micrometers), PM2.5 (Particulate matter with diameter of 2.5 micrometers or less), and PM10 (Particulate matter less than 10 micrometers diameter), are attracted increasing attention [1, 2]. Those are regarded as the chief culprit of the air pollutions and concealed in the morphologies of dust, smoke, powder or fog. The chemist, environmentalist, and meteorologist et al agree on the pollutant components of oxides of nitrogen (NOx, the oxidized No readily forms No2, nitrogen dioxide), monoxide (Co), sulfur dioxide (So2), ozone (O3), methane (CH4), metals or metalloid. Naturally, the chemical ingredients involved water soluble ions, such as anions No^{3-} and $So4^{2-}$ formed mainly from oxidation of So2 and NOx, and arsenic, cadmium, nickel, mercury and lead etc. Those play a key role to produce PM currently [3]. Those chemical ingredients impair our organs and tissues, many studies have indicated that exposure to air pollution can increase risks of developing cancer, respiratory and allergy diseases, and aggravate the condition of people suffering from respiratory or heart diseases [1,4].

Within our limited atmosphere, the high-quality air attracts a variety of profits, even has a therapeutic effect on human health, and also brings on much social welfare enjoying ourselves of outdoor interests and activities on recreation and leisure in the free high-quality air. On the one hand, people present a high demand for various beautiful natural environments included inhalational absorbable fresh air, and many tremendous economic values on extraordinary sight of tourism sites. On the other hand, devastating of the human economic activities not only counteracts our health, but also sometimes erodes environment. The air possesses the characteristic of non-market resource, under many situations, the marketable prices of non-market resources may not exist. Nevertheless, the non-existence of price does not mean zero economic value to be accrued to those non-market resources, neither are their values very low. The value assessment of those environmental goods is comprehensively proposed, which contributes to compensating for the reduction of the fresh air and boosting the conservation of the high-quality air.

For the nonmarket public good non-evaluated by mean of market price, the total economics value (TEV) included use and nonuse value (existence, bequest, and option), is preferred to scholar's research on the environmental economic values [5]. One instrument which is commonly used to measure economic value on non-market resource is the consumer surplus hypothetically acted as a price or value. Furthermore, the related literatures have long

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spatiotemporal spans and have been prosperous till now, and the value is frequently measured through Contingent Valuation Method (CVM) and Choice Experiment Model (CEM), which have been used in many research fields such as healthy, risk, waste, environment etc [5-7].

At present, the atmospheric modeling can solve some complex environmental problems aiming at forecasting [8] what are statuses of No2, Co, So2, O3, CH4, metals or metalloid toxins in order to improving air quality. Furthermore, which can help fostering a more informed and creative environmental programming and respond to the challenges to science practice with other stakeholders such as politics, governance, media, etc [9]. Additionally, econometric approaches are used to analyze the air pollution trend through time series or conventional statistic analysis [10]. The purpose of this research is to measure the marginal effect of air quality diversity to help decision-making environment, and the study is an update and extension of current research on air quality. The new methodology holds three-stage sequential procedures consisted of assessing economic value through CVM after surveying individual state preference, achieving demand function by regression analysis of the partial factors mentioned above, and exploring marginal effect and analyzing finally.

EXPERIMENTAL PART

Hicks summarized important findings in his paper "The Four Consumer's Surpluses" published at journal of The Review of Economic Studies (Vol. 11, No. 1, Winter, 1943, pp.31-41), and explored the distinct relations between the corrected measures of consumer surplus and Marshallian measure. CV (Compensating variation), EV (Equivalent variation), CS (Compensating surplus) and ES (Equivalent surplus) were primarily systematically introduced and argued in the content, which benchmarked Hicks consumer surplus.

According to environmental microeconomic foundation, the four consumer surpluses can be used to explain Willingness to Pay (WTP) or Willingness to Accept (WTA). WTP, the maximum expected value by an individual, is worthy of procuring a good (CV or CS) or avoid something with low quality (EV or ES). WTA is the minimum monetary amount to be worth accepting to a low quality or undesirable good (CV or CS), or abandoning the good (EV or ES). When not directly consuming by participants in the experiment, the consumers determine to acquire a good's value through their WTP, for example, WTP for the air is the expected value of a high-quality air. CV expresses the effect of a price change on an agent's net welfare at the context of new prices and the initial utility level, which is widely used to measure mean WTP per capita and the consumer surplus.

When thinking about the indifference curves of two goods, let price vector $\mathbf{P}=\{p_1^1,p_1^2,p_2^1,p_2^2\}$, where $\mathbf{P}^1=\{p_1^1,p_1^2\}$ & $\mathbf{P}^2=\{p_2^1,p_2^2\}$, $p_2=p_2^1=p_2^2$ is constant variable respectively, the wealth level is M, and an expenditure function is e (P, u). Adopted the traditional method in virtue of the expenditure function of utility u and price P, the derivative through Shephard Lemma is calculated to get Hicks demand function $h_1(\mathbf{P},u_0)$ .Thereupon then, consumer surpluses are achieved through the function's integrals, shown at Equ1.

$$CV=\mathrm{e}\left(p_1^{\,2},\mathrm{u}_0\right)-\mathrm{e}\left(p_1^{\,1},\mathrm{u}_0\right)=\int_{p_1^2}^{p_1^1}h_1(\mathbf{P},u_0)dp_1=\int_{p_1^2}^{p_1^1}\frac{\partial e(\mathbf{P},u0)}{\partial p1}dp_1 \quad (1)$$

Hypothetical, the utility functions of the air good are $u_0(\mathbf{P}^1,\mathbf{M})$ before improving and $u_1(\mathbf{P}^2,\mathbf{M}-CV)$ in the high-quality condition to ensure getting the consistency utility, that is, $u_0(\mathbf{P}^1,\mathbf{M})=u_1(\mathbf{P}^2,\mathbf{M}-CV)$. Through indirect utility function, $v(p,y)=\max u(x)=[x^*(p,y)]\ s.t.\ \ p\cdot x\le y$, get $u_0(\mathbf{P}^1,y)=u_1(\mathbf{P}^2,y-WTP_{\max})$ for maximized willingness to pay, while $u_1(\mathbf{P}^2,y-WTP)>u_0(\mathbf{P}^1,y)$ for individual willingness to pay variable.

Any good expression on demand elasticity like the air can be written as follows:

$$E_D=(\Delta Q/Q)/(\Delta P/P)=(\Delta Q/\Delta P)\cdot(P/Q) \quad \text{or}$$

$$E_D=(dQ/dP)\cdot(P/Q) \quad (2)$$

An ordinary good or service is suitable for use of the law of diminishing returns, a fundamental principle of economics. Marginal utility can be used to analyze the utility change of increasing or decreasing in unit consumption of the good or service. Nevertheless utilization of demand function is ineffectiveness on disposing of the marginal utility, but marginal effect equal to the reciprocal of the coefficient is adequate for solving the change of any explanatory variable owing to increasing or decreasing in unit good consumption, and brings on indirect explanation of the utility change. The marginal effect can be defined as the following equation.

$$ME=\Delta P/\Delta Q=1/(\Delta Q/\Delta P) \text{ or } ME=1/(\partial Q/\partial P) \quad (3)$$

RESULTS AND DISCUSSION

Sampling and survey

The dichotomous choice (DC) empirical survey is easier on the respondents, though it statistically requires a larger sample to attain a given level of precision. The background explanation is one of the crucial steps to get the credible data, and the paper explores a new state preference survey mode through the actual air quality apperception.

In the light of Technical Regulation on Ambient Air Quality Index, there are six AQI levels promulgated by Environmental Protection Ministry of China. Each level is a clustering of many integrated AQIs in the series, and every AQI is the maximization of calculated individual AQI of So2, No2, CO, O3 etc. The first four AQI levels are grouped according to four aggregations every other 50 AQIs of sort ascending. The level 5 is an aggregation of AQIs equal to 201-300, and the level 6 is collected AQIs more than 300. Based on the classifying AQI levels, the choice date of the surveyed layout is fixed on the date of AQI level 3, 4 and 5, helping to respondent apperception and perceived comparison with high-quality air. Meanwhile, the greatly high-quality air is also disclosed and introduced.

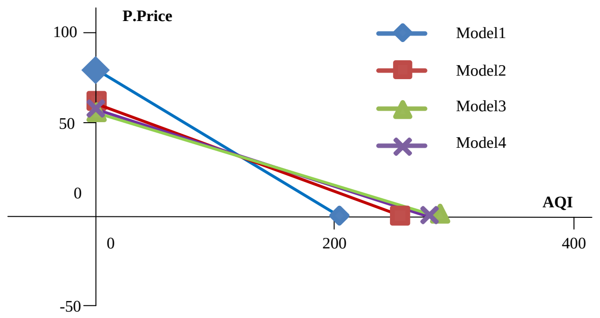

Fig. 1. Air demand function curves of three state preference survey scenarios

The questionnaires are simplification with double/single bounded DC (DBDC/SBDC) items (biding and optioning items) and several socio-economic variables of sex, age, income, education and occupation, for the purpose of acquiring samplings rapidly and largely. The biding value variable is named as *BIDV*. To sum up the empirical survey, three scenarios are respectively chosen to achieve surveys on March, May or June in Tianjin, and each investigation is implemented 3 days per capita.

The paper also necessarily employs an empirical sampling of top-down approach to obtain the data. Base on clustering data from the official websites, China Meteorological administration, Ministry of Environmental Protection of People's Republic of China, Tianjin Environmental Protection Bureau, and Tianjin Meteorological Bureau, 245 samplings are gained. The descriptive statistics can be browsed at Tab. 1.

Estimating Hicks' consumer surplus

The paper adopts an empirical sampling of bottom-up approach to obtain the data. Two CVMs included SBDC and DBDC is used to calculate Hicks' Compensating variation (CV) which is a deputy of the consumer surplus or the mean WTP per capita, equal to the existence value to be used to similarly reflect TEV per capita, named pseudo price (P. Price) of the air or the other ubiquitous type of public goods. The marginal value (mean WTP per capita) represents the hypothetical price of the public good (air) on several dozens of AQI amount. The computing results are shown at Tab. 2.

In the maximum likelihood estimation, measures of goodness-of-fit and joint significance of the coefficient are often estimated by McFadden's R^2 and the likelihood ratio, while McFadden's R^2 cannot be used to calculate the double-bounded Logit model. Through comparison among the three asymptotically equivalent tests including the likelihood ratio statistic, the Wald statistic, and the Lagrange multiplier statistic, Wald statistic can be exploited in the context of the double-bounded DC model because of its utilization based solely upon the value of the unrestricted likelihood function. For the six models at tab. 2, the variable coefficient is statistically significant: SBDC is tested by LR-ratio and McFadden pseudo R^2, and DBDC through LR-ratio and Wald test.

Calculating air demand function

The interesting factors comprise of the three chemical (Co, No2, and So2) and four atmospheric (temperature, dew, humidity, and wind speed) factors, AQI and AQI's levels (the classification of AQIs). According to the definition of the chemist, environmentalist, and meteorologist et al, the AQI's levels enbody the compositive explanation of many factors (pm2.5, pm10, So2, No2, O3, and Co etc). Assumptions in the paper is: (i) the AQI firstly is taken as the supposed demand quantities of the ubiquitous air, and (ii) individual economic value represents the hypothetical price of the air quality reckoned with the process above. The early analysis and research of the author (Li, in publishing) shows that, although the influences of the atmospheric factors are synchronously occurred and statistically significant, if their cross-influences are not considered better, the evident impact will contort their truly acted results. In this paper, the regressed consequence emerges the disordered situation of regression involved with the atmospheric factors; therefore the air demand function ignores their influences. According to classification of the three scenarios mentioned above, the author utilizes the trend extrapolation approach to acquire the other Mean (WTP) at different AQI level. And then pseudo price is respectively computed through an equably transformation of Mean (WTP). Thereupon then, a new variable is created to exhibit the air value assimilated top-down data.

The ordinary least square method (Model1 and Model2) and the two stages least squares (Model3 and Model4) are used to achieve the regression equation of air demand function, the solution and statistic test shown at Tab.3&4, which presents the strictly statistic significance at each model, except that the regressed coefficients or marginal effects of No2 and So2 are not commonsensible apperception at Model 1 of Tab. 3. Their reversed deflection seems to be influenced by AQI's definition, that is to say, squeezing out a maximization of many individual contamination's AQIs cannot imply the associated factors or independents' regression relationship in existence, and thus the paper develops Model 2-4 of Tab. 4. The explanatory variables, PM2.5, PM10 and CO, express the acceptable correlation, and get the indicative marginal effects of scarce elasticity.

Based upon the estimation results of the air demand functions, their air demand function curves are drawn at Fig. 1, which depicts an instinctive illustration on demand characteristics of the air good to rely on the individual state preference survey. Certainly, the newly designed survey mode can clearly perceive the survey background, adding up short-term survey can reduce the error, whereas a cognized attention span of AQI amount can hardly aim at an individual state preference WTP at the limited scenarios. The hypothesis is there are approximately the exclusive correspondence between a large number of AQI and a small quantity of WTPs.

Analyzing marginal effect

At model 1 from Tab. 5, the new increase of unit AQI arouses the marginal effect of PM10 reached 16.7 times, and 2.3 times PM2.5. According to Model 3&4, the air good's pseudo price represents the approximate unit elasticity, while at Model 1&2, PM10, PM2.5 Co, No2, So2 etc impact on the pseudo price to an insufficient elasticity, which demonstrates that the air pollution can bring about a calamitous influence of human health and environmental safety.

In this paper, the marginal effect resultings present that the increased unit AQI will give rise to the average individual WTP decreased in 0.2 to 0.4 Yuan, raising 0.1 Co concentration can induce the AQI at one unit high, and the PM2.5's or PM10's concentration respectively goes up 2.3 and 16.8 to lead to the air quality impaired one index. Which expresses that PM10 concentration engenders the larger effect on human health.

Table 1. Descriptive Statistics on the relative factors of air quality

	Mean	Std. E.	Median	Variance	Skewness	Kurtosis	Min	Max
AQI	131.10	4.21	112	4341.23	1.060	0.603	30	361
Level	3.02	0.07	3	1.30	0.496	-0.792	1	5
PM2.5	94.03	3.88	77	3682.22	1.286	1.670	12	330
PM10	154.76	5.38	139	7097.35	1.108	1.478	21	476
Co	1.91	0.06	1.67	0.76	1.286	1.721	0.45	5.57
No2	60.61	1.49	57	541.47	0.659	0.117	16	129
So2	70.56	3.22	55	2540.22	1.022	0.576	4	261
Tem	9.77	0.66	8	108.28	0.275	-1.219	-8	31
Dew	-1.22	0.66	-3	107.67	0.165	-0.803	-25	19
Hum	52.84	1.15	52	325.95	0.058	-0.797	15	95
Spd	11.27	0.34	10	27.98	1.307	2.083	3	32
P. Price	30.55	0.93					7	58

Table 2. Evaluating air quality through two modles under three scenarios

	Scenario1				Scenario2				Scenario3			
	SBDC		DBDC		SBDC		DBDC		SBDC		DBDC	
Variables	Const	*BIDV*	Const	*BIDV*	Const	*BIDV*	Const	*BIDV*	Const	*BIDV*	Const	*BIDV*
Coefficient	0.043	-0.012	0.882	-0.015	0.018	-0.010	0.803	-0.012	0.430	-0.009	0.672	-0.011
t-statistic	0.153	-3.114	4.183	-7.551	0.066	-2.695	4.074	-7.500	1.573	-2.944	3.424	-7.732
t-probability	0.878	0.002	0.000	0.000	0.947	0.007	0.000	0.000	0.116	0.003	0.001	0.000
Mean	108.472		115.00		114.622		108.34		120.991		151.78	
Observations	106				111				115			
LR-ratio	18.765		205.306		15.762		187.934		17.548		193.515	
McFadden	0.141				0.110				0.116			
Wald test			57.013				56.251				59.787	
Mean(WTP)	81.080		68.395		96.485		81.533		114.575		90.058	

Table 3. Air demand function estimation (Model 1)

	(Constant)	P. Price	PM2.5	PM10	CO	No2	So2
Coeff.	159.669	-2.451	0.429	0.060	8.010	-0.225	-0.070
S.E.	8.926	0.156	0.070	0.044	3.276	0.111	0.045
t	17.888	-15.755	6.137	1.341	2.445	-2.023	-1.561
Sig.	0.000	0.000	0.000	0.181	0.015	0.044	0.120
Adj. R Sq.				0.923			

Table 4. Air demand function estimation (Model 2-4)

	Model 2		Model 3		Model 4	
Variable	(Constant)	P. Price	(Constant)	P. Price	(Constant)	P. Price
Coefficient	259.839	-4.214	280.212	-4.881	279.617	-4.861
S.E.	3.611	0.107	4.466	0.136	4.417	0.134
t	71.957	-39.470	62.743	-35.997	63.305	-36.294
Sig.	0.000	0.000	0.000	0.000	0.000	0.000
Adj. R Sq.	0.865		0.841		0.844	
instrumental			PM10,PM2.5		PM10, PM2.5 Co, No2, So2	

Table 5. Price elasticity and marginal effect of demand function

	Mode1	Mode 2	Mode 3	Mode 4	Mode1				
	P. Price				PM2.5	PM10	CO	No2	So2
$-\partial Q/\partial P$	2.451	4.214	4.881	4.861	-0.429	-0.060	-8.010	0.225	0.070
$-E_D$	0.571	0.982	1.137	1.133	-0.308	-0.070	-0.117	0.104	0.038
$-ME$	0.408	0.237	0.205	0.206	-2.330	-16.780	-0.125	4.452	14.292

CONCLUSIONS

This paper mainly gropes for the economic value and marginal effect of air quality change through creating the demand function of air attributed an omnipresent public good. The key contributions are (i) providing an analytical framework of ubiquitous public good's demand, (ii) predicting air economic value based on Hicks consumer surplus, (iii) defining and analyzing the marginal effect of the independents based upon the air demand function. As well as, the surveys comply with two approaches of bottom-up and top-down technique, and samplings of the field investigation on individual state preference and the official websites' data clustering are combined organically.

The marginal value (mean WTP per capita) is measured; meaning that newly increasing dozens of AQI amount can arouse WTP with 68.4 Yuan at the scenario of AQI level 3, 81.5 Yuan at the scenario of AQI level 4, and 90.1 Yuan at the scenario of AQI level 5. Meanwhile, according to analysis of marginal effect, the decreased one unit AQI (to improve air quality) leads to the average individual willingness to pay in 0.2 to 0.4 Yuan, and Co's, PM2.5's and PM10' marginal effect respectively is 0.1, 2.3 and 16.8, which indicates that PM10 emerges a bigger change during improving air quality at one AQI reduced, that is to say, PM10 concentration brings about the larger effect on human health.

Acknowledgements: *This study was funded through Tianjin Philosophy Social Science Fund , China (No.TJGL13-018).*

REFERENCES

1. http://www.epa.gov/airtrends/2011/.
2. A.B. Vicente, T. Sanfeliu, M.M. Jordan, *Journal of Environmental Management*, 108, 92 (2012).
3. A. M. Taiwo, D.C.S. Beddows, Z Shi, *Science of the Total Environment*, **475**, 29 (2014).
4. http://www. sciencedaily.com/ releases/2010/05/ 100510161244.htm.
5. I.J. Bateman: Valid Value Estimates and Value Estimate Validation: Better Methods and Better Testing for Stated Preference Research. In: Bennett, J. (Ed.). The International Handbook on Non-Market Environmental Valuation. Edward Elgar Publishing, Cheltenham UK. 2011.
6. J. Armbrecht: *Tourism Management*, **42**, 141 (2014).
7. G. Marella, R. Raga, *Waste Management*, **34**(7), 1199 (2014).
8. X. Luo, H. Cao, *Procedia Environmental Sciences*, **12**, 159(2012).
9. M. Vedrenne, R.Borge J. Lumbreras, M.E. Rodríguez: *Environmental Modelling & Software*, **57**, 177 (2014).
10. S. Mehta, H. Sbihi, T.N. Dinh, D.V. Xuan, L.L.T. Thanh, C.T. Thanh, G.L. Truong, A. Cohen, M. Brauer, *Atmospheric Environment*, **95**, 571 (2014).