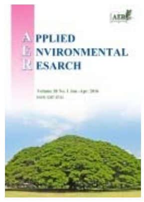
Applied Environmental Research

Journal homepage : http://www.tci-thaijo.org/index.php/aer



Loss of Value in House Properties due to Air Pollution in Map Ta Phut Industrial Area of Thailand

Nararuk Boonyanam

Faculty of Economics at Sri-racha Kasetsart University, Sri-racha, Chonburi 20230, Thailand
* Corresponding author: Email: noaratc@gmail.com; Phone: +66895312079

Article History
Submitted: 8 June 2016/ Accepted: 2 August 2016/ Published online: 17 October 2016

Abstract

Air pollution in the Map Ta Phut Industrial Estate in Thailand, has caused increasing risk of death, injury and health problems for local residents. Existing control measures are ineffective due to weak law enforcement. Although the problem has drawn a lot of attention, the monetary value of the impacts of air pollution in Map Ta Phut is not known. The objective of this paper was to estimate the economic cost of air pollution damage in Map Ta Phut using the Hedonic Pricing Method, with 192 house samples. The results showed that the marginal willingness to pay (MWTP) for a one unit reduction of AQI level was THB 2,815 or around USD 80, or each unit increase in air pollution would result in an estimated loss of THB 2,815 or around USD 80 in house price. The total value of losses to housing from one unit of air pollution in Map Ta Phut which is comprise of 38 communities was THB 119.3 million (about USD 3.4 million). Detection of the loss of value has implications for local residents, housing development investors, factories, and government and environmental institutions to manage air pollution as their top priority as well as to evaluate the efficiency of existing measures and budget to deal with the problem more appropriately.

Keywords: Hedonic pricing method; Home price, Air pollution; Map Ta Phut

Introduction

Map Ta Phut residents have suffered from various forms of pollution, especially air pollution caused by frequent chemical leaks and emissions from factories in the Map Ta Phut Industrial Estate, located in Rayong province, Thailand. Operations began in 1990, and the estate now hosts 140 industrial plants, including 45 petrochemical factories, 8 coal-fired power plants, 12 chemical fertilizer factories and 2 oil refineries [10]. A total of 56,591 residents (excluding a large non-registered population of 102,362), live in the Map Ta Phut municipality [12]. In 1997, pollution came to public attention when 1,000 pupils and teachers at a local school were admitted to hospital after inhaling toxic emissions. People living and working in the Map Ta Phut area had 65 percent higher levels of genetic damage to blood cells than people living in rural areas of the same province. Cell damage, which is a precursor to cancer, was 120 percent higher for refinery workers than for residents of Rayong Province's rural communities [14]. One-third of the children in Map Ta Phut had both short-term memory dysfunction and visual-motor coordination deficits and there was a relationship between the short term memory dysfunction and community, living period and distance from residential area to the industrial park [2]. Viwatpanich [22] found that in 2003, rates of cervical, bladder, breast, liver, nasal, stomach, throat and blood cancers were highest in Rayong compared to other provinces. Recent evidence from both developed and developing countries points to a direct exposure-response relationship between air pollution and acute respiratory infections in adults and children [6, 7, 23, 24]. World Health Organization [23] reported that both women and children suffer from acute respiratory illness from air pollution which is responsible for nearly one-third of all deaths in children under 5 years old in developing countries, while Touloumi [21] found that an increase of 50 μg/m^3 of NO_2 was associated with a 2.6 percent increase in asthma admissions and a 1.3% increase in daily all-causes mortality. In Turkey, it was found that the new air quality standard for particulate matter smaller than 10 μm (PM_{10}) resulted in reductions in minor respiratory symptoms by 11, 8, and 4.4 cases per person in Afsin-Elbistan, Kutahya-Tavsanli and Ankara, respectively [1]. A recent study in Rome found a relationship between outdoor NO_2 and CO levels and admissions for respiratory diseases [8]. In Thailand, Jadsri et.al. [11] found excessive risk of respiratory disease and disease clusters among communities near the Map Ta Phut Industrial Estate. In addition, strong relationships between respiratory disease and emissions of SO_2, NO_2, and total solid particulates (TSP) were found. People who lived closer to the industrial estate were associated with more acute respiratory problems and adults aged over 40 years were more likely to have respiratory symptoms and eye irritation than those under 40 years, with females more likely to be affected than males [18]. The number of local residents in Map Ta Phut who fall sick from air pollution has increased over the years, especially after 2005 as shown in Table 1.

Table 1: Number of people in Map Ta Phut affected by air pollution

Year	Dead	Injured	Respiratory diseases	Total population	Percentage affected
1999	2	412	-	n/a	n/a
2000	-	142	-	14,055	1.01
2001	-	-	-	n/a	n/a
2002	-	-	-	n/a	n/a
2003	-	-	-	n/a	n/a
2004	-	19	-	n/a	n/a
2005	-	143	11,113	38,382	29.33
2006	-	55	12,745	40,999	31.22
2007	-	60	15,970	43,892	36.52
2008	-	438	18,959	45,646	42.49
2009	-	111	21,223	50,185	42.51

Reported modified as relevant from [15]

Figure 1 shows that the number of people suffering from respiratory diseases is the highest among the top five diseases in Rayong and there is a tremendous gap between the highest (respiratory disease) and the second highest (digestive system diseases). Furthermore, the number of people with respiratory disease in Rayong is also the highest in the country [15].

Air quality standards or air quality index (AQI) in Thailand cover five defined pollutants: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3) and particulate matter smaller than 10 µm (PM_{10}). Air pollutant levels of these criteria in Map Ta Phut typically exceeded the environmental standards at all monitoring stations across the area (Table 2). Viwatpanich [22] reported the number of days when air pollutants exceeded their standard level each year in Map Ta Phut from 2004-2010, as shown in Table 2. The data showed a surge in the number of days when O_3 exceeded the standard during 2007 and 2008, and it reached a high of 33 days in 2010.

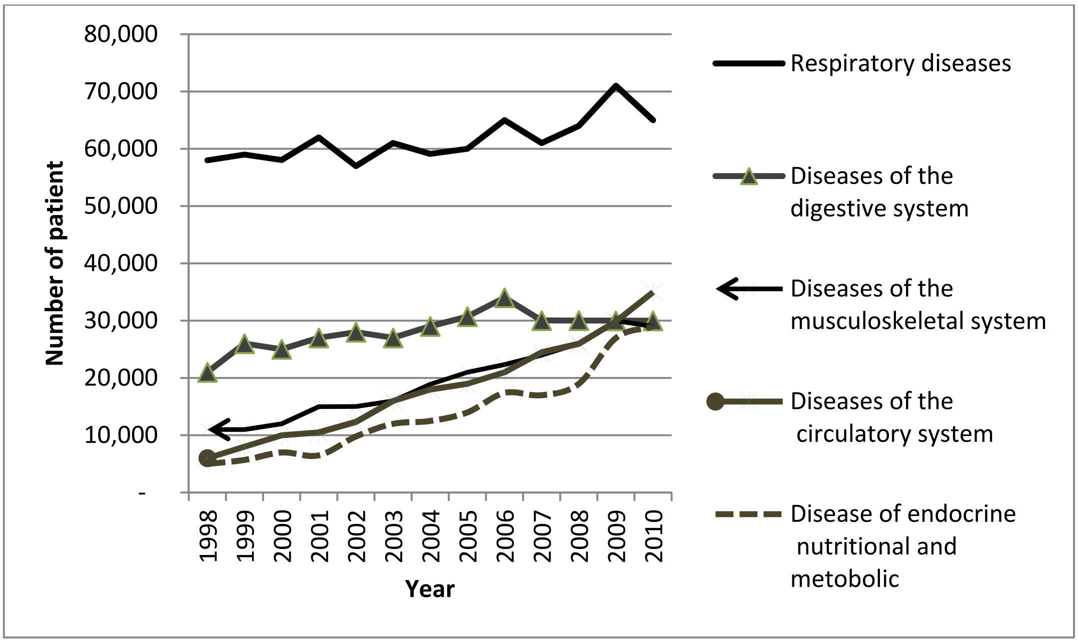


Figure 1 Top five diseases in Rayong province [15]

Table 2 Air pollution report in Map Ta Phut during 2004-2010 [22]

Year	Maimum pollutant concentration (ug/m^3)					Number of days>Std.				
	PM_{10}	SO_2	NO_2	CO	O_3	PM_{10}	SO_2	NO_2	CO	O_3
2004	123.2	104	56	8	100	6	0	0	0	0
2005	103.7	66	63	3.2	116	0	0	0	0	3
2006	133.6	63	52	1.5	123	3	0	0	0	4
2007	127.5	49	58	1.7	134	1	0	0	0	3
2008	168.3	86	59	1.8	125	2	0	0	0	10
2009	117	47	63	1.3	136	0	0	0	0	30
2010	93.2	37	53	1.4	133	0	0	0	0	33

Moreover, the average level in 24 hours of emissions of volatile organic compounds (VOCs) also exceeded the standard, especially for benzene which was almost twice the maximum set under the standard, although some argue that the benzene standard (PCD) used is very strict (stricter than Japan's) and that it is quite hard for Industry to control benzene emissions to comply with the standard (Table 3). VOCs are used in the manufacture and maintenance of building materials, interior furnishing, cleaning products and personal care products. They contain carbon and evaporate at room temperature; exposure may cause irritation to the eyes, nose and throat, sometimes resulting in headaches, nausea and neurological problems. In addition, some VOCs are classed as carcinogens.

The Map Ta Phut city plan has also changed every 3-5 years, resulting in increased chemical exposure risk for local residents. The plans for 1988 and 1991 showed that the industrial area was limited to a small area, as compared to the 2003 plan, which extended the industrial area to cover the 'yellow zone,' classed as residential areas in the 1988 and 1991 plans. Clearly, these residential areas had expanded during 1988-1991 according to the plan. Since a house is not a property that can be removed easily like other assets, most families have remained in the area for many generations, so they cannot simply leave the area in response to repeated changes in the city plan. In practice they are left with no option other than to live in close proximity to heavy industrial plants. Therefore, during the field interview survey, a number of residential homes and villages were found to be located in the middle of the industrial estate.

The government took action to address the problem only after severe conflict erupted between residents in the Map Ta Phut Municipality and the local government office. These actions involved command and control, compensation, incentive measures and the creation of the Action Plan for Toxic Reduction and Removal in Rayong Province 2007-2011. However, the attempts have met with limited success as there was no real enforcement of these measures [3]. The Office of National Environment Board (ONEP) declared the Map Ta Phut Municipality and its surrounding areas as a "Pollution Control Area" on March 3, 2009 followed by the temporary suspension of 76 projects under construction because they did not comply with the environmental provisions of the Kingdom's new Constitution. However, the older, heavily polluting plants were still allowed to continue operations unimpeded. This narrative points to the lack of real interest and commitment by the authorities, which resulted partly due to lack of knowledge of the economic and monetary loss caused by air pollution.

Table 3 Volatile organic compound (VOCs) levels in 2009 in Map Ta Phut [22].

No.	VOCs type	Standard (ppb)	Average level in 24 hrs.
1	Vinyl chloride	10.00	0.16
2	1,3 Butadiene	0.33	0.40
3	Dichloromethane	22.00	0.46
4	Chloroform	0.43	0.08
5	1,2 Dichloroethane	0.40	0.53
6	Benzene	1.70	3.10

Many studies have been conducted on Map Ta Phut; however, most have focused on the causes and effects of air pollution as a health risk. Viwatpanich [22] found that air and water pollution in Map Ta Phut stemmed from a poor treatment systems in seven major industrial plants. The factors that most affected air pollution control policy were: people's perception of the policy, the government management system and the capability of government officers. Chomkrod [5] examined the effectiveness of air pollution measures which applied to the petrochemical industrial factories in the Map Ta Phut Industrial Estate and found that the law tends to focus on emission standards, ignoring cumulitive impacts caused by emissions or the assimilative or carrying capacity of the area. Therefore, existing measures are unable to prevent and control air pollution. The Thailand Environment Institute [19] and Thai Universities for Healthy Public Policy [20] reported facts and figures on air pollution, health risk and the city plan in Map Ta Phut together with a preventive plan and a follow up plan to provide an overall picture of the current situation.

In other countries, there have been an enormous number of hedonic property value studies to explore possible associations between air pollution and falls in property value. In Indonesia, it was found that ambient levels of SO_2, lead and total hydrocarbons (THC) had a negative impact on house prices and per family value of clean air in Jakarta, and that people would pay USD 28, USD 38.72 and USD 85, respectively, for a reduction of 1 unit of the mentioned air criteria [24]. In France, there was a strong impact of distance from hazardous industrial facilities on housing values [9]. Smith and Huang [17] reviewed over 50 hedonic studies for US cities between 1967 and 1988 and concluded that the marginal willingness to pay (MWTP) for a one unit reduction of particulate matter was in the range USD 0-98.52. Boyle and Kiel [4] reviewed the hedonic studies for 12 US cities between 1992 and 2000 and reported an estimated value of SO_2 concentration, in the range USD 58-USD 328/$\mu g/m^3$. Despite an enormous number of hedonic studies on air pollution and house price, none have yet been reported for Map Tha Phut. This research therefore aimed to fill this gap by asking the research question “What is the cost of the air pollution damage in Map Ta Phut?” The rest of the paper is organized as follows. Section 2 discusses the data and methodology employed for this study, Section 3 presents the results, while Section 4 covers discussion and Section 5 the conclusions and implications of this study.

Methodology

The study site comprised 3 communities situated around the two selected air monitoring stations (Figure 2): Mapchalood-Charkklang, Sanam Pao and Kangamphur-Tangpai. In total, there are 12 air monitoring stations in Rayong: New Town Map Ta Phut, Nongfeb, Krokyaicha, Takuan Public Health Service Centre, Map Ta Phut Health Promoting Hospital monitoring station, Rayong Agriculture Office monitoring station and six other stations that belong to the BLCP Power Plant. The most polluted and least polluted areas were selected to represent the whole range within the area. One monitoring station that recorded a high polluted air quality index is located in Mapchalood-Charkklang community and is called the Map Ta Phut Health Promoting Hospital monitoring station and the other station recording a low polluted air quality index is located between the Sanam Pao and Kangamphur-Tangpai communities and is called the Rayong Agriculture Office monitoring station. Each selected area was within a one-kilometer radius of the monitoring station.

The hedonic pricing method (HPM) was used in the study as it has the advantage of incorporating opportunity cost into the analysis. Both the revealed preference and stated preference techniques are non-market valuation techniques that take opportunity cost into account when evaluating environmental goods. The two revealed preference techniques include the travel cost method (TCM) and the hedonic price method (HPM) while the stated preference techniques are represented by the contingent valuation method (CVM) and the benefit transfer method (BT). Air pollution enters the utility function of potential house buyers; therefore, the cost of air pollution damage can be estimated through the loss of value in house price. Although the HPM suffers from theoretical and empirical problems such as requirements for strong assumptions, the standard argument of the stated preference method such as CVM is that it is entirely based on the subjective opinion of the participants. Since Matos et al. [13] proved that both methods produce similar results, the researcher adopted the HPM for this study.

In this study, the HPM was used to estimate the structural characteristics, neighborhood characteristics and air pollution factors that affect house pricing. In HPM, houses constitute a product class differentiated by characteristics such as the number of rooms and size of lot. The price of a house can be taken to be a function of its structural, neighborhood and environmental characteristics. More formally, let H represent the product or commodity class-housing; then any unit of H, say h~, can be completely described by a vector of its characteristics, including locational, neighborhood and environmental characteristics [5].

The price of the house *(PH)* (Eq. 1) is a function of structural characteristics, neighborhood characteristics and air pollution. The structural variables are type of the house *(Detach)* and this study focused only on detached houses and townhouses, the age of the house *(Age)*, number of bedrooms *(Bed),* number of bathrooms *(Bath),* utility area *(Area),* and land size *(Lot).* Neighborhood variables were main road location *(Main)* and distance to business center *(Discbd).* The environmental variables were *AQI,* SO_2, NO_2, *CO,* O_3, PM_{10}, and 6 major *VOCs* which are vinyl chloride *(VC),* 1, 3 butadiene *(BT),* dichloromethane *(DM),* chloroform *(CF), 1,2* dichloroethane *(DE)* and benzene *(BZ).* There were two hypotheses for this study; the first hypothesis was that the house price is positively affected by all structural characteristics and neighborhood variables. The second hypothesis was that the house price is negatively affected by all air pollution variables.

Figure 2 Map of houses sampled
Source: https://www.google.co.th/maps/@13.067671,101.0203449,12z

$$PH = f(\text{Structural, Neighborhood, Air pollution}) \quad \text{(Eq. 1)}$$

The first attempt was to use the semi-log functional form by applying the ordinary least square method (OLS). However, the effect of the significant variables was too high and severe heteroskedasticity resulted. Therefore a Box-Cox transformation was introduced to test for the appropriate functional form and correct the problem of heteroskedasticity. Box and Cox (1964) developed the transformation and argued that the transformation could make the residuals more closely normal and less heteroskedastic. A general Box-Cox transformation on a single variable is specified as either Eq. 2 or Eq. 3 depending on λ value.

$$y^{(\lambda)} = (y^{\lambda} - 1)/\lambda \text{ for } \lambda \neq 0 \qquad \text{(Eq. 2)}$$
$$y^{(\lambda)} = \ln y \text{ for } \lambda = 0 \qquad \text{(Eq. 3)}$$

Box-Cox obtains the maximum likelihood estimates of the parameters for four different models; theta model, lambda model, left-hand-side-only model (lhsonly) and right-hand-side-only model (lhsonly). The most general of the models is the theta model and is specified as:

$$y^{(\theta)} = \alpha + \sum_i \beta_i x_i^{(\lambda)} + \sum_i \gamma_j z_j + \varepsilon \qquad \text{(Eq. 4)}$$
$$\text{where } y^{(\theta)} = (y^{\theta} - 1)/\theta;\ x_i^{(\lambda)} = (x^{\lambda}_i - 1)/\lambda$$

where y is the house price, x_{ij} is the vector of variables to be transformed, z_{ij} the vector of other non-transformed variables which include dummy variables and variables that are not strictly positive, λ is the parameter of the transformation, α, β, and γ are the vectors of coefficients to be estimated and ε is the error term. A less general model than the theta model is the lambda model. It specifies that the same parameter be used in both the left-hand-side and right-hand-side transformations and is specified as:

$$y^{(\lambda)} = \alpha + \sum_i \beta_i x_j^{(\lambda)} + \sum_i \gamma_j z_j + \varepsilon \qquad \text{(Eq. 5)}$$
$$\text{where } y^{(\lambda)} = (y^{\lambda} - 1)/\lambda;\ x_i = (x^{\lambda}_i - 1)/\lambda$$

More restrictive than a common transformation parameter is transforming the dependent variable only; this model is called the lhsonly model and is specified as:

$$y^{(\theta)} = \alpha + \sum_i \beta_i x_j + \varepsilon \qquad \text{(Eq. 6)}$$

The fourth model transforms only a subset of the independent variable and is called the rhsonly model and is specified as:

$$y = \alpha + \sum_i \beta_i x_i^{(\lambda)} + \sum_i \gamma_j z_j + \varepsilon \qquad \text{(Eq. 7)}$$

The implicit price for continuous characterristics, x_i is calculated by taking the partial derivative of the price of y with respect to x_i:

$$\partial y/\partial x_i = \beta_i x_i^{\lambda-1} y^{\,1-\theta} \qquad \text{(Eq. 8)}$$

The implicit price for a non-transformed or dummy variable, z_j is calculated by taking the partial derivative of the price of Y with respect to z_j:

$$\partial y/\partial z_i = \gamma_i y^{\,1-\theta} \qquad \text{(Eq. 9)}$$

The population is the number of households in communities surrounding the two selected air monitoring stations. The number of households in the Mapchalood-Charkklang community was 531, in Sanam Pao was 697 and in Kangamphur-Tangpai was 384. The total population was 1,612 households. Total sample size was 200 households which was around 10 percent of total population [16]. Quota sampling was employed for this study, based on the population size of each community. 66 samples were taken from Mapchalood-Charkklang, 86 from Sanam Pao and 48 from Kangamphur-Tangpai community. Air quality data were obtained from the Pollution Control Department Report, while house price and other data were sourced from interviews. The air quality data covered the month of January 2016, when the interviews were conducted. There were no air pollution data for each individual house in the area, therefore there is no variation in pollution data across houses. However, tremendous variation in air pollution levels was measured between the two selected areas around the air monitoring stations, for example the AQI[1] level of the Map Ta Phut Health Promoting Hospital monitoring station was as high as 60 while the AQI level at the Rayong Agriculture Office monitoring station was 33. After cleaning the data set, the final sample size was 192.

Results

Descriptive statistics are presented in Table 4, which shows that the average house price in Map Ta Phut was THB 1,750,461 where the average house age was 13 years, and contained an average three bedrooms and two bathrooms. Average land size was 191.63 m^2. Average distance to the district center was around 7 km. In addition, less than half of the sample houses were located on the main road. Half of the sample houses were detached, and the other half was townhouses which provided a representative sample of each house type. All these attributes showed that the houses in the Map Ta Phut area belonged to middle to upper-middle class families.

Table 4 Descriptive statistics

Variable		Unit	Mean	TD.DEV.
Dependent variable				
PH	House price	THB	1,750,461.00	867,495.30
Structural Characteristics				
Detach	House type	1=house, 0=townhouse	0.49	0.50
Age	House age	Year	12.84	14.02
Bed	Number of bedroom	rooms	2.47	0.62
Bath	Number of bathroom	rooms	1.84	0.57
Area	Utilization area	square meter	141.49	146.64
Lot	Land size	square meter	191.63	219.12
Neighborhood Characteristics				
Discbd	Distance to district center	meter	6,740.13	7,978.17
Main	Main road location	1=main road, 0=otherwise	0.29	0.46
Air Pollution				
SO_2	Hourly average concentration of SO_2	ppb	5.05	3.91
NO_2	Hourly average concentration of NO_2	ppb	19.29	2.93
CO	8 hour average concentration of CO	ppm	0.99	0.10
O_3	Hourly average concentration of O_3	ppb	32.14	1.47
PM10	Daily average concentration of PM10	ug/m^3	82.57	32.76
VC	Daily average concentration of VC	ug/m^3	0.21	0.04
BT	Daily average concentration of BT	ug/m^3	1.20	0.77
DM	Daily average concentration of DM	ug/m^3	0.79	0.01
CF	Daily average concentration of CF	ug/m^3	0.19	0.01
DE	Daily average concentration of DE	ug/m^3	0.56	0.10
BZ	Daily average concentration of BZ	ug/m^3	2.15	0.20
AQI	Daily average concentration of AQI	-	43.30	13.20

Note: [1] The air pollution level of AQI between 0-50 = Excellent, 51-100 = good, 101-150 = lightly polluted, 151-200 = moderately polluted, 201-300 = heavily polluted and 300+ = severely polluted.

A correlation test showed perfect correlation between the air pollution criteria variables as well as VOCs substances, therefore only AQI was used to represent the ambient level of air pollution and the remaining air pollution criteria along with the VOCs were therefore omitted from the analysis to avoid multicollinearity problems that may reduce the precision of the estimate. The non-normality problem was corrected using a boxplot to identify data outliers; eight outliers were removed from the analysis. After removal of these outliers, the total sample was 192. The results of Box-cox transformations are presented in Table 5.

Table 5 Hypothesis test for Box-Cox transformation

Characteristic Variables	Box Cox Transformation lhsonly Model	rhsonly Model	Lambda Model	Theta Model
Structural Characteristics				
Detach	434.886***	391,533.500**	3.048**	10.738*
	(26.884)	(5.373)	(5.310)	(3.356)
Age	-0.398	-45,908.140	-0.247	-2.656
	(0.033)	(0.300)	(0.751)	(0.265)
Bed	156.273***	286,382.10	3.289**	17.640
	(6.852)	(0.976)	(4.344)	(2.115)
Bath	262.351***	569,925.700***	4.093***	22.805***
	(17.368)	(7.381)	(10.071)	(7.779)
Area	-0.408*	-166,003.900	-0.178	0.131
	(3.087)	0.427	(0.302)	(0.000)
Lot	0.440***	1,561,252.000***	1.480***	241.498***
	(7.316)	(9.930)	(14.003)	(19.346)
Neighborhood Characteristics				
Discbd	-0.029	-80,836.090	-0.035	-13.424
	(1.765)	(0.106)	(0.027)	(0.080)
Main	-73.568	-184,539.000*	-1.488*	-6.970
	(1.094)	(3.260)	(2.703)	(2.265)
Air Pollution				
AQI	9.955	-1,144,197.000	-2.144	-144.509*
	(0.590)	(1.101)	(0.511)	(3.582)
Constant	596.9216	2488.723	58.813	0.810
AIC	2180.956	2187.270	2175.152	2170.988
BIC	2183.286	2189.601	2177.483	2175.649
Lambda	-	-0.178	0.175	-0.461*
s.e.	-	(0.295)	(0.172)	(0.324)
Theta	0.476***	-	0.175	0.288**
s.e	(0.171)	-	(0.172)	(0.160)
Loglikelihood	-1089.478	-1092.6351	-1086.5762	-1083.494
LR chi-square	103.740	107.750	109.54	115.710
Chi-square for reject Ho				
when X = -1	65.790***	4.750**	51.670***	57.830***
when X = 0	7.680***	0.350	1.130	7.290***
when X = 1	9.120***	2.810*	14.930***	21.090***

The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) were used to select the most suitable Box-Cox model from the four functional forms. The theta model had the lowest AIC and BIC value, suggesting that it provides the best transformation. The theta model produced a value of θ of 0.288 and the value of λ was -0.461 and yielded the best transformation. The rejection of parameters test of the theta model under the null of θ = λ = 1, 0, or -1 indicated that linear and log-log linear model were not suitable functional forms. In addition, the lhsononly model test result also suggested that the semi-log functional form should be rejected although the model was not of the best fit. Since all simpler functional forms were rejected, a Box-Cox transformation was used as a functional form for this study. The use of the Box-Cox transformation as a functional form (not just as a test) of choice in hedonic regression has generally received strong support in the literature [25, 26]. The final regression model was as shown in Eq.10.

The regression result showed that four out of nine variables were significant, namely: house type, number of bathrooms, air quality and land size. The signs of the significant variables were as expected. The air pollution level was negatively correlated with house price, while house type, number of bathrooms and land size were positively correlated, confirming both our research hypotheses. The negative sign of the air pollution variable indicated that people are concerned about air pollution levels. The implicit price for significant continuous characteristics and non-transformed or dummy variables can be calculated using equations (8) and (9).

$$y^{(0.288)} = 0.810 + 10.738Detach + 22.805Bath^{-0.461} + 241.498Area^{-0.461} - 144.509AQI^{-0.461} \quad \text{(Eq. 10)}$$

where $y^{(0.288)} = \frac{y^{0.288} - 1}{0.288}$, $x_i^{-0.461} = \frac{x^{-0.461}{}_i - 1}{-0.461}$, x_i = Detach, Bath, Area and AQI

The implicit price in Table 6 indicates that the greatest effect on house price is house type. The price difference between detached houses and townhouses was around THB 300,000. The second highest effect was from number of bathrooms, followed by air pollution. It was surprising to find that the effect of air pollution was greater than that of the land size variable. (Air pollution factors are typically found to have less impact on house price compared to physical components and location of the house). The coefficient of the AQI variable suggested that better air quality is associated with a higher house price. The result is straightforward. The marginal effect of a change in one unit of AQI or it can be interpreted as the marginal willingness to pay (MWTP) for a one unit level reduction in AQI or air pollution of THB 2,815 or around USD 80. The land size variable had the smallest effect on house price. One additional square meter of land size will increase the house price by THB 2,221. The result is consistent with the land price appraisal report of the Treasury Department which indicated that the land price per 4 m^2 in the Mapchalood-Charkklang community which has a high polluted air quality index was THB 10,000, while the land price per 4 m^2 in the Sanam Pao and Kangamphur-Tangpai communities which have a low polluted air quality index was between THB 40,000 and THB 60,000. The model can be used to calculate average house prices that have certain structural and environmental characteristics which benefit both local residents and housing development agents.

Table 6 Implicit price of significant variables

Significant variable	Variable type	Coefficient (β_i, γ_i)	$x_i^{\lambda-1}$	$y^{1-\theta}$	Implicit price
Detach	Dummy	10.738		27869.2022	299,259.4933
Bath	Continuous	22.805	0.010373	27869.2022	6,592.8421
Lot	Continuous	241.498	0.000330	27869.2022	2,221.2702
AQI	Continuous	-144.509	0.000699	27869.2022	-2,814.5760

Discussion

The study results confirm an association between air pollution and house price in Map Ta Phut. The MWTP for a one unit reduction of AQI level was calculated as THB 2,815 or around USD 80. The result was similar to that found by [24] for Jakarta city in Indonesia which reported that the MWTP for better air quality was in the range USD 28.34-USD 85.39 or around THB 995 to THB 2,998. The result obtained from Map Ta Phut was quite low in the range compared with evidence from a developed country such as the USA (reported by Boyle and Kiel [4] as in the SO_2 range of USD 58 to USD 328/ $\mu g/m^3$). There are 38 communities in the Map Ta Phut Municipality, comprising 42,392 households. Therefore, the total loss of value in house property from air pollution damage in the Map Ta Phut Municipality per unit of AQI is around THB 119.3 million or about USD 3.4 million. This figure is in the housing sector only and is a result of one unit change or a marginal change in the air pollution damage level. Therefore, in reality, the actual monetary loss should be much higher, as normally the air pollution level changes by more than the marginal value. The huge economic loss identified by this study indicates that the problem should be treated as a top priority over public health and safety to avoid tremendous accumulation of economic loss in the future. Better budget allocation, better law enforcement and better cooperation should be adopted immediately before the crisis grows beyond our capability to deal with it.

Conclusions and implications

House property values in Map Ta Phut depend on their structural characteristics and air pollution levels. The structural characteristics that affect house price are house type, number of bathrooms, air quality and land size. Only an aggregate parameter in the form of Air Quality Index (AQI) was tested due to the multicollinearity problem between air pollution criteria variables as well as VOCs. The type of house contributes the highest effect to house price compared to the effect of additional bathrooms, air quality and lot size, indicating that people in the study area were more concerned about house type than number of bathrooms, air quality and lot size. Factors such as utility area, house age, number of bedrooms, distance to district center and location of the house were found to have no effect on house price. Housing development agents should take the variables with a large effect on house price into account–house type, number of bathrooms, air quality level and lot size. –when developing a housing project. Local residents should consider relocating or selling their house in Map Ta Phut area to prevent further loss to their house value if air pollution levels show no sign of improvement. By recognizing the large loss from air pollution damage in Map Ta Phut, the government, environmental institutions and industrial factories should be able to better manage their priorities and be more concerned about dealing with the air pollution level more appropriately.

References

[1] Ara, S., Tekes, C. 2016. The monetary valuation of acute respiratory illness from air pollution in Turkey. Atmospheric Pollution Research, 7(2016): 82–91.

[2] Aungudompukdee, P. 2009. Factors related to neurobehavioral effects in young children residing near petrochemical industrial estate: A community-based cross-sectional study in Map Ta Phut sub-district, Rayong province, Thailand. Ph.D. dissertation, Chulalongkorn University.

[3] Boonpraderm, C. 2010. The implementation effectiveness of the air pollution control policy of the Map Ta Phut Industrial Estate. Ph.D. dissertation, Ramkhamheang University.

[4] Boyle, M.A., Kiel, K.A., 2001. A survey of house price hedonic studies of the impact of environmental externalities. Journal of Real Estate Literature, 9(2): 117–144.

[5] Chomkrod, J. 2009. Legal measure for the protection and control of air pollution from petrochemical industrial factories: Case study of Map Ta Phut Industrial Estate. Thesis, Thammasat University.

[6] Ezzati M., Kammen D. 2001. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure–response study, The Lancet Public Health, 58(9282), 619–624.

[7] Freeman, A. M.1979. Hedonic prices, property values and measuring environmenttal benefits: A survey of the issues. The Scandinavian Journal of Economics, 81(2): 154–173.

[8] Fusco D., Forastiere F., Michelozzi P., Spadea T., Ostro B., Arca M. *et al.* 2001. Air pollution and hospital admissions for respiratoty conditions in Rome, Italy. European Respiratory Journal, 2001(17): 1143–1150.

[9] Grislain-Letremy, C., Katossky, A. 2014. The impact of hazardous industrial facilities on housing prices: A comparison of parametric and semiparametric hedonic price models. Regional Science and Urban Economics, 49(2014): 93–107

[10] Industrial Estate Authority of Thailand. 2012. About Map Ta Phut Industrial Estate. http://www.ieat.go.th/main/default/index/pass/1. [Accessed on May 3, 2014].

[11] Jadsri, S., Singhasivanon, P., Kaewkungwal, J., Sithiprasasna, R., Siriruttanapruk, S. Konchom, S. 2006. Spatio-temporal effects of estimated pollutants released from an industrial estate on the occurrence of respiratory disease in Map Ta Phut municipality, Thailand. International Journal of Health Geographic, 5: 48–55.

[12] Map Ta Phut Municiality. 2011. Map Ta Phut population number as of December 2012. http://mtp.go.th/public/content/% E0%B8%82. [Accessed on May 4, 2014].

[13] Matos, J.C.B., Flindell, I., Masurier P.L., Pownall, C. 2013. A comparison of hedonic price and stated preference methods to derive monetary values for aircraft noise disturbance and annoyance. Transportation Research Part D, 20(2013): 40–47

[14] Peluso, M., Srivatanakul, P., Munnia, A., Jedpiyawongse, A.,Meunier, A., Sangrajrang, S.,Piro, S.,Ceppi, M., and Boffetta, P. 2008. DNA adduct formation among workers in a Thai industrial estate and nearby residents. Science of the Total Environment, 389: 283-288.

[15] Rayong Provincial Public Health Office. 2011. Rayong disease statistics report. Rayong Provincial Public Health Office: Rayong.

[16] Sawatdiyakorn, J. 1978. Principle and research methodology in social science. Bangkok: Supan Publishing.

[17] Smith, V.K., Huang, J., 1995. Can markets value air quality? A meta-analysis of hedonic property value models. Journal of Political Economy, 103(1): 209–227.

[18] Tanyanont, W. Vichit-Vadakan, N. 2012. Exposure to volatile organic compounds and health risks among residents in an area affected by a petrochemical complex in Rayong, Thailand. Southest Asian Journal of Tropical Medicine and Public Health, 43(1): 201–211.

[19] Thailand Environment Institute. 2011. Academic stage for Map Ta Phut: Map Tha Phut situation, pollution, health, and city plan. Thailand Environment Institute: Nonthaburi.

[20] Thai Universities for Healthy Public Policy. 2011. The strategic environment framework: SEF project to become eco industrial town: A case study of Map Ta Phut. www.hsm.chula.ac.th/maptaphut/ air-maptaphut.pdf [Accessed on November 2, 2014].

[21] Touloumi G., Katsouyanni K., Zmirou D., Schwartz J., Spix C., de Leon AP *et al.* 1997. Short-term effects of ambient oxidant exposure on mortality: a combined analysis within the APHEA project. Air Pollution and Health: a European Approach. American Journal of Epidemiology, 146: 177–185.

[22] Viwatpanich, K. 2012. Suffering from industrial estate development: A case study in Map Ta Phut, Thailand. International Seminar on Population and Development, 1: 32–47.

[23] World Health Organization. 1977. World Health Report 1997. http://www.who.int/entity/whr/ 1997/en/whr97_en.pdf?ua=1 [Accessed on July 24, 2016].

[24] Yusufa, A.A., Resosudarmob, B.P. 2009. Does clean air matter in developing countries' megacities? A hedonic price analysis of the Jakarta housing market, Indonesia. Ecological Economics, 68(2009): 1398–1407.

[25] Williams, B. 2008. A hedonic model for internet access service in the consumer price index. Monthly Labor Review, July (2008): 33–48.

[26] Maureen L. C., Leland B. D., Kenneth E. M. 1988. On the choice of functional form for hedonic price functions. Review of Economics and Statistics, November (1988): 668–675.