Willingness-to-pay for a Haze Adaptation Program and a Haze Eradication Program in Singapore: The 2015 Transboundary Haze*

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Abstract

In Southeast Asia, the seasonal transboundary haze pollution stemming from slash-and-burn practices of traditional Indonesian farmers affects several countries in the region including Indonesia, Singapore, Malaysia, and Brunei. Despite both domestic and regional efforts that have been put in place to help fight against haze, Southeast Asian haze remains a long-term issue that recurs in a varying degree of intensity during every dry season in the region. While we remain optimistic that the problem will eventually be resolved, given that most of these fires are the result of human activity, solutions can be executed successfully only in the longer run. In the interim, one of Singapore's options is to adapt. A contingent valuation (CV) survey on 793 Singapore residents was conducted in Singapore between November and December 2017 to elicit their willingness-to-pay (WTP) for a haze adaptation program and a haze eradication program in Singapore. We use a double-bounded dichotomous choice CV survey design and the Kaplan-Meier-Turnbull method and the probit regression to infer the distribution of Singapore residents' WTP for the two programs and find that they are willing to pay between S$ 46.46 and S$ 60.06 for a haze adaptation program that reduces the local impacts of haze and between S$ 51.66

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and S$ 66.76 for a haze eradication program. These findings suggest that Singapore residents continue to value the government's effort to derive solutions to resolve the haze crisis that recurs intermittently.

1. Introduction

In Southeast Asia, transboundary haze pollution stemming from slash-and-burn practices from traditional Indonesian farmers affects several countries—particularly Singapore, Malaysia, and Brunei—regularly during the southwest monsoon season between June and September. Besides transboundary haze, the trend of farmers moving away from the clearance of dryland forests to peatland forests is also a concern, as peatlands are major carbon sinks and, when burned, contribute extensively to carbon dioxide and particulate pollution (Biswas and Tortajada 2018). In Singapore, the haze crisis has recurred intermittently over the years. Records show that the issue of haze has troubled the country from as far back as 1972, with the hazy conditions surfacing at the beginning of October that year and getting increasingly worse. Visibility was so low that motorists had to drive with headlights even on brightly lit streets due to the thick haze. In October 1977, Singapore again was blanketed with smoky haze, which was blown in from forest fires originating in Sumatra. In the 1980s, there were irregular episodes of haze, primarily due to forest fires originating from Kalimantan. In September 1997, the Pollutant Standard Index (PSI)[1] hit an all-time high of 226 due to fires in Indonesia caused by the large-scale burning of forested land. The smoky hazy conditions lasted approximately two months. June 2013 was the first time that the PSI level hit the hazardous range. This time, the Indonesian authorities claimed that the severity of haze was partially caused by the widespread burning of forested land in Indonesia by palm oil companies owned by Malaysian and Singaporean investors. Those episodes were superseded in September 2015 when Singapore experienced hazy conditions for close to two months. On some days, PSI crossed the hazardous mark. Primary and secondary schools were closed, outdoor activities at the Sports Hub were suspended, and fast-food chains halted their delivery services. Some of the 2015 FINA Swimming World Cup events were cancelled as the PSI was in the unhealthy range.

1 PSI is calculated based on the 24-hour average concentration levels of various pollutants. Singapore's ambient air quality is continuously monitored through a network of air monitoring stations strategically positioned throughout the city-state. These monitoring stations assess the levels of particulate matter (PM10), fine particulate matter (PM2.5), sulfur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3), and carbon monoxide (CO). These six pollutant parameters collectively determine the PSI. The PSI value serves as an indicator of air quality, with the following classifications: 0–50 represents "Good," 51–100 signifies "Moderate," 101–200 indicates "Unhealthy," 201–300 represents "Very Unhealthy," and values exceeding 300 are deemed "Hazardous." During haze episodes, PM2.5 is the dominant pollutant.

Several actions, both domestic and regional, have been put in place to help fight against haze. In September 1994, a Haze Task Force was formed to coordinate the efforts of the Singapore government against haze. The Task Force consists of representatives from more than 20 government agencies who meet annually to prepare for the dry season from June to September. It aims to protect public health and safety by working with the Indonesian government to reduce the burning of forested land as well as maintain social and economic resilience. The Singapore government also stockpiles N95 masks to distribute to various retail outlets. These masks are usually given out for free to low-income families. Medical health subsidies are also given to vulnerable groups of residents such as the elderly and young children during haze outbreaks. Regional efforts have started since the 1980s to control forest fires in Indonesia. After the haze outbreak in 1997, ASEAN enhanced the 1995 ASEAN Co-operation Plan on Transboundary Pollution into the Regional Haze Action Plan with the objectives of preventing forest fires through more effective policy management and enforcement, establishing proper mechanisms to monitor forest fires, and strengthening firefighting capacity.

In 2002, the ASEAN Agreement on Transboundary Haze Pollution was created as a legally binding environmental agreement to reduce haze pollution in Southeast Asia and was signed by all members. Malaysia was the first to ratify it at the end of 2002 and Singapore ratified it at the beginning of 2003. Indonesia, as the main haze-producing party, was the last country to ratify the agreement in 2014, signaling the concerns of the government in controlling and preventing illegal slash-and-burn practices in the country. In 2014, Singapore also passed the Transboundary Haze Pollution Law, which aims to deter local and foreign companies from engaging in haze-polluting activities that affect Singapore. The reality is that errant companies cannot be accurately identified without proper legislation and institutional capacities of Indonesia, however.

According to the Coase Theorem, in a situation of low transaction costs where the assignment of property rights is feasible, optimal control of pollution can be achieved. However, the conventional Coase Theorem cannot be applied and made feasible in the case of Southeast Asian transboundary haze pollution because identifying ownership of property rights or entitlements can be challenging. Does the polluting country have the right to pollute? Or does the polluted country have the right to clean air? Other pressing points are the independence and sovereignty of both polluting and polluted countries and the lack of a supranational authority to assign and enforce the rights of countries to haze-free clean air. As such, it is not within the authority of Singapore to effectively reduce haze pollution at its source.

The idea of a stakeholder approach to cost-sharing in the context of seasonal haze in Southeast Asia has been a contemporary debatable issue (Quah and Johnston 2001). The polluter-pay principle, which refers to the idea that polluters are responsible to pay for their negative externality generated, is unlikely to be successful in mitigating haze pollution. Another plausible alternative is the victim-pay principle, which means that it would be more cost-effective to help polluters by paying them an amount on the condition that the plantations adopt land-clearing practices without the use of fires.

The polluter-pay principle is unlikely to be successful in mitigating haze pollution for at least two reasons. The first is equity issues. A uniform across-the-board Pigouvian taxation or boycotting of products that contribute to the haze may penalize both errant and law-abiding ones. In addition, as raw materials such as palm oil, which are harvested from slash-and-burn practices, are often used as intermediate goods in the production of final goods, the additional costs of a Pigouvian tax will be passed on to firms and end consumers who are not responsible for directly causing the fires without any prior consent whether they are willing to pay more for such goods. Moreover, smaller-scale firms do not have the financial resources that larger firms have to ditch slash-and-burn methods and would close if forced to switch to expensive methods. The second is about free-riding issues, which limit the effectiveness of a Pigouvian tax. As a handful of firms in Singapore have signed a declaration that their products are free of raw materials from suppliers being investigated for the Indonesian fires, other smaller firms who are not as reputable have less incentive to commit since they may feel that they can conveniently enjoy the benefits of better-quality air through the efforts of these bigger brands and are less likely to be under scrutiny individually. Other than cost issues in switching to less fire-intensive methods, there may be an intangible cost incurred to smallholders who are accustomed to respecting the intergenerational tradition of slash-and-burn practices and a lack of understanding of the damages that haze can create for society. The same applies to consumers, as they can just free-ride on a select few who make bulk purchases of such goods without changing their purchasing behavior. Considering that smallholders were estimated to contribute about 40 to 80 percent of the haze, free-riding would still result in the overproduction of activities that contribute to the haze even if larger firms are compliant (Chander and Quah 2018).

Given that the polluter-pay principle cannot be effectively applied to mitigate transboundary haze pollution, what about the victim-pay principle? Theoretically, if the new utility of victims from gaining the tangible and intangible benefits of better air quality minus the cost of contributing a monetary amount is higher than the status quo of not paying this amount to do something additional about the haze, then the victim-pay principle can work. These payments can be used to fund the appropriate land-clearing agricultural equipment, financial incentives, and disincentives to small landholders to stop slash-and-burn practices (Quah and Moeller 2018). Governments can pay rewards or subsidies to small landlords who use haze-free methods. The reward system may encourage polluters to switch to cleaner production methods. Given the economic benefits that Indonesia receives from clearing peatlands by fire, not only a reward system should be put in place, but farmers would also expect compensation contributed by the polluted countries to be sufficiently large to offset the economic incentives the polluter gains from polluting. However, realities seldom work as easily as economic theory. For such a victim-pay principle to work, the underlying assumptions are that people are willing to pay for not enduring pollution and farmers are willing to respond to economic incentives. Additionally, compensation should be contributed not only by countries that are worst affected but also by those that are least affected to avoid free riders.

To understand and solve the haze problem, knowing the damage costs of the haze for all polluted countries in aggregate is important. The costs of transboundary haze can be classified into tangible and intangible costs. Tangible costs are costs associated with the reduction of goods that are directly traded in the market and are easily quantifiable with secondary data. On the other hand, intangible costs are not tied to market values and are less observable. In the context of transboundary haze, tangible costs include health costs, loss of income from retail and tourism, loss of productivity from work absenteeism, and expenditure on haze protective equipment such as air purifiers and face masks. Intangible costs are general discomfort suffered by the public due to haze and loss of enjoyment of outdoor activities, which can only be estimated by direct elicitation of societal preferences. Even if symptoms are mild, an appealingly pleasant environment can affect an individual's well-being and productivity. If the importance of an appealing pleasant environment is recognized, then it is possible that reduced visibility and choking smoke caused by haze would have some impacts on an individual's mental state.

Haze pollution has been recognized as a major public concern in affected countries such as Indonesia, Malaysia, and Singapore; many studies in the literature are found to focus on assessing the economic costs of transboundary haze pollution on these countries (Tacconi 2003; Othman et al. 2014; Quah et al. 2021). These studies, though useful, tend to focus only on the tangible aspects of haze pollution and ignore completely the intangible aspects, namely, the general discomfort suffered by the public during haze and loss of enjoyment from outdoor activities. To date, little remains known about the value that the public places on the benefits of reducing haze pollution. To avoid an underestimation of haze damage costs to society, economic valuation would have to include both possible tangible and intangible costs.

Despite all these potential challenges in solving the recurring transboundary haze problems, we remain optimistic that the problem will eventually be resolved. However, with most of these fires being a result of human activity, solutions can be executed successfully in the longer run. Given these limited alternatives, while waiting for mitigation efforts to take place in Indonesia, which are likely to take a long time to be realized, in the interim, Singapore's option is to adapt. Therefore, instead of paying the polluter to fund appropriate land-clearing agricultural equipment and providing financial incentives to small landholders to stop slash-and-burn practices, alternatively, payment could be used to fund haze adaptive programs such as timely dissemination of information on air quality, provision of face masks and subsidized health care for haze related illnesses, and better work-from-home arrangements. As the source of the haze is beyond the country's borders and to avoid the political and economic uncertainties of cooperating with international authorities to stop slash-and-burn practices, we posit that funding a haze adaptation program in Singapore, tied to the cost of the haze in Singapore, maybe more realistic in the short run.

The objectives of the paper are two-fold. First, we aim to estimate the intangible cost of haze pollution, which can be interpreted as the general discomfort suffered by the public during haze. Theoretically, the amount of money individuals are willing to pay for haze-free clean air should be equal to the welfare they obtain from clean air (Mishan and Quah 2007), which in turn should be equal to the discomfort suffered by them due to haze. Second, if haze is here to stay, in the interim, it is crucial to know how much individuals are willing to pay for an adaptive program in Singapore. Such an estimate is useful in the decision-making processes of policymakers, particularly to justify how much resources should be spent in funding adaptive programs in the country during the interim when the country's option is to adapt. Singapore residents' willingness to pay for these programs is elicited using a double-bounded dichotomous choice contingent valuation survey that is estimated using a non-parametric Kaplan-Meier-Turnbull model and a probit model.

We design a contingent valuation survey on two scenarios to elicit respondents' willingness to pay (WTP) for the adaptation program and eradication program and hence clean air all year round. In the first scenario, we ask the respondent their WTP for a haze adaptation program where the government can implement measures to reduce the local impacts of haze through timely dissemination of information on air quality, provision of face masks, and subsidized health care and permission to work-from-home and study-from-home during the haze period. In the second scenario, we elicit the respondent's WTP to pay for the haze eradication program imagining that the polluter can effectively stop slash-and-burn practices and hence solve the annual haze pollution so that air quality in the country will always be within a good range all year round. During the survey, we also informed the respondent that the duration of haze is one month. We conducted a contingent valuation (CV) survey on 793 Singapore citizens and Singapore permanent residents[2] aged 21 years and above between November and December 2017. The participants were randomly selected from five different regions in Singapore (Central, West, North, East, and North East) for face-to-face interviews.[3]

2 In selecting the sample size, confidence level is taken as 95 percent and confidence interval is 3.5.

3 The data used here are based on the year of 2015. For additional details, please refer to Quah et al. (2021).

In the analysis, we believe that the differences across respondents' WTP of the adaptive program and the eradication program are attributable to variations in both observed characteristics, such as respondents' demographic characteristics and/or other attributes, as well as unobserved, random variations. Our model includes several variables to account for the variations in observed respondent characteristics. These include variables such as whether the respondents have sufficient knowledge about haze (K) and their concerned attitudes toward haze (A). The inclusion of these variables is motivated by the work of De Pretto et al. (2015), who show that people with higher levels of knowledge and concerned attitudes toward haze will have a greater likelihood of engaging in protective practices. In our study, we aim to assess whether there exist any potential correlations between respondents' knowledge about haze and their concerned attitudes toward haze on their WTP for the haze adaptation program and the haze eradication program in Singapore. Additionally, we also include in the regression an estimate of how respondents' concerns about the environment and their health affect their WTP value. Other variables are air quality rating, respondents' perception about future haze situations, annoyance level, whether respondents have any underlying health problems, spending in treatment due to haze, and spending on masks and air purifiers during haze. Demographic variables included are occupational exposure, outdoor leisure, age, gender, race, education level, income, marital status, number of children in the household, household size, and whether the respondents are sole breadwinners.

We use both the non-parametric Kaplan-Meier-Turnbull method as well as the probit regression to infer the distribution of Singapore residents' willingness to pay for both the haze adaptation program and the eradication program. The Kaplan-Meier-Turnbull method suggests a mean WTP of S$ 46.46 for the adaptation program and S$ 51.66 for the eradication program if the duration of haze lasts for a month. The probit model provides higher estimates of S$ 60.06 for the former and S$ 66.76 for the latter.

This paper is organized as follows: Section 2 presents a review of the relevant literature on studies that share similarities with our own research in terms of their nature and objectives. Section 3 outlines our survey design, empirical method, and procedures. Section 4 examines the results from the survey and the empirical methods performed to analyze significant relationships between explanatory variables and WTP. Section 5 discusses policy implications based on findings from the results and provides recommendations. It also serves as the conclusion of this paper.

2. Literature review

Lin et al. (2017) estimated the economic impacts of haze on Singapore using a CV survey where they asked Singaporeans their WTP for haze-free air. That study showed that the mean WTP is about 0.97 percent of Singaporeans' annual income and estimated that total national WTP is $643.5 million per year with a lower estimate of $527.7 million and an upper estimate of $765 million. As the surveys were carried out shortly after the 2015 haze event, this event was likely to be prominent in the mind of the respondents when they stated their WTP for haze mitigation.

Other studies that used the CV method as an assessment method in eliciting the public's WTP for haze management and prevention include the work of Wang et al. (2016), who conducted a survey in Jiangsu Province of China, where they concluded that the public's WTP for haze management and prevention is about RMB 96.53 and the total non-market value for haze management and prevention in Jiangsu is RMB 7.65 billion. Sun et al. (2016) assessed the value of WTP for smog mitigation using a nationwide face-to-face CV survey conducted in July 2014 and found that the mean WTP for smog mitigation is RMB 1590.36 per year.

3. Survey design and empirical methods

3.1 Survey design

The CV survey consists of seven main sections. More specifically, in section 1, the questionnaire begins by obtaining some personal characteristics of the respondents, including their citizenship (i.e., Singaporean or Singapore permanent resident), age, and region of residency. The objective of the section is to identify qualified respondents, as respondents who are non-citizens or non-Singapore permanent residents or below the age of 21 years are not eligible to participate. These requirements increase the likelihood of surveying taxpayers, given that our payment vehicle, as discussed later, is annual tax, which can help to generate more meaningful WTP levels.

Sections 2 to 4 consist of a set of questions that allow us to compute scores on respondents' awareness about haze (Knowledge), attitude toward haze (Attitudes) and protective behavior against haze (Practices). Toward this direction, in the Knowledge section, 10 True/False/Not Sure questions are used to gauge the level of respondent's awareness about haze. Correct answers are given 1 point, incorrect answers are given −0.2, and 0 point is given if the respondent is uncertain about the answer. For the Attitude section, 14 questions based on a 5-point Likert scale are used to gauge the level of respondent's worries and health concerns toward haze. The scale uses an increasing scale of agreement with "1" being "Strongly Disagree" and "5" being "Strongly Agree." Questions include statements such as "Nothing can be done by the Singaporean government to improve the haze situation" and "Nothing can be done from my part to improve the haze situation." Five Likert scale questions that aim to identify respondent's concern about the environment are included, with "1" being "Strongly Disagree" and "5" being "Strongly Agree." Questions from this section help to gauge the level of importance the respondent places on enjoying a cleaner environment. Two questions also ask the respondent how they would

Figure 1. Singapore without haze (Picture A) and with haze (Picture B). (The authors thank Agence France-Presse (AFP) for granting permission to use their images.)

Picture A **Picture B**

rate the air quality in Singapore (Environment rating) and how they foresee air quality in Singapore (Positive Forecast) 10 years from now. Our questionnaire survey does not have a full section to explicitly gauge the Practices aspect of the KAP like De Pretto et al. (2015), but some aspects of it are accessed by asking respondents how much money they spent on haze protection items such as masks and air purifiers.

Two WTP questions are designed to elicit a respondent's WTP for adaptation measures and eradication and hence clean air all year round. The section begins by first showing two pictures of a prominent landmark at Marina Bay Sands of Singapore, with one showing no haze (Picture A) and another with the landmark blanketed by smoky haze (Picture B) as indicated in Figure 1. We elicit the annoyance level to provide context to the severity of the haze situation that adaptation measures aim to address based on public funding. The respondent is reminded that most often they will see the surrounding environment like Picture A (Good) without haze. One day when they wake up they notice that the surroundings are as of Picture B (Unhealthy) with haze and this experience will continue for a duration of one month. We ask the respondent to indicate the level of annoyance using a 10-point Likert scale.

After that, the respondent is presented with two hypothetical scenarios: The first scenario is adapting to the environment (Adaptation) and the second scenario is eradicating haze completely (Eradication). The two scenarios are as follows:

(1) **WTP for Adaptation (WTP1):** Suppose that the annual haze pollution continues to occur and hence you will wake up with haze as of Picture B (Unhealthy). This experience will continue for a duration of one month. However, the local government can implement measures to reduce the local impacts of haze through:

- Timely dissemination of information on air quality.
- Provision of face masks and subsidized healthcare for haze related illnesses during the haze period.
- Designing and encouraging work-from-home and study-from-home arrangements during the haze period.

(2) **WTP for Eradication (WTP2):** Imagine that a pro-environment collaboration project involving Singapore and countries in the surrounding region could effectively stop "slash and burn" practices and hence solve the annual haze pollution issue so that the Pollutant Standard Index (PSI) would remain in "Good" range of 0–50 all year round.

In the Adaptation scenario, the respondent is asked: "Are you, as an individual, willing to pay S$ X per annum through taxes to fund these measures that would reduce the local impacts of haze?" In the Eradication scenario, the respondent is asked: "Are you, as an individual, willing to pay S$ X per annum through taxes to fund this project which would allow the PSI in Singapore to remain in the 'Good' range of 0-50 all year round?"

Information about WTP is obtained through double-bounded dichotomous choice payment questions. Commonly used elicitation methods in CV surveys include open-ended questions, iterative bidding games, payment cards, and dichotomous choice. Dichotomous choice can be further subdivided into single-bounded or double-bounded formats. This study applies the double-bounded dichotomous choice format proposed by Carson et al. (1986) because dichotomous formats are incentive-compatible, they simplify cognitive tasks faced by respondents as respondents only have to make judgments regarding the acceptability of the price they are offered, and the answer sequences yield clear bounds on WTP and constrain the part of the distribution where respondents' WTP can lie. Hanemann et al. (1991) proved that the double-bounded dichotomous choice is asymptotically more efficient than the single-bounded model.

Respondents are randomly assigned a first bid amount with predetermined lower and higher follow-up bids used if the respondent answers "no" or "yes" to the initial bid, respectively. X is a randomly chosen bid from one of the three pre-determined values of S$ 25, S$ 50, and S$ 100. Those who answer "no" are asked if they would pay S$ 0.5X and those who answer "yes" are asked if they would pay S$ 2X. The bid vectors are: [S$ 12.50, S$ 25, S$ 50], [S$ 25, S$ 50, S$ 100], and [S$ 50, S$ 100, S$ 200]. To reduce warm-glow and hypothetical bias, respondents were reminded of their budget constraint and substitute spending alternatives.

For our study, although respondents may be willing to pay a lesser amount when it involves raising taxes but willing to pay a larger amount when the money is contributed to a special fund for the same purpose, we use annual tax as our payment vehicle as it is more realistic that haze adaptation measures and eradication efforts are perceived as a competing resource from the government. Additionally, using annual tax as the payment vehicle also simplifies the cognitive valuation task of respondents. Wang and Mullahy (2006) and Wang et al. (2016) used donation as the payment vehicle. EPRI et al. (2006) used higher cost of living as an additional payment vehicle on top of annual tax.

A reservation price of zero may indicate genuine indifference to the increase in the provision of haze management measures, so these are true reflections of their preferences and hence should be included in estimating the true mean WTP. However, some zero bids may be reported by respondents even though they place a positive value on the non-market good being valued. These zeros are known as *protest zeros*. Protest zeros present a selection bias for the data collected and neglecting it will lead to downward biased estimates (Sun et al. 2016). Such a phenomenon can be due to a variety of reasons including free riding, adverse reaction to interviews, or concern about fairness in public administration. This is inevitable even in the best-designed CV study. Therefore, to identify such protest zeros, we add an additional follow-up question in the questionnaire after the two WTP questions to inquire further into the motivation behind the answer of refusal to pay so that enough information can be collected to determine whether the zero bids are true zeros that should be regarded as a genuine indifference to haze or a protest zero. Specifically, if a respondent registers a zero WTP in the WTP questions for either adaptation or eradication, we inquire about the motivation of refusal to pay to determine whether the zero WTP stated should be regarded as a protest zero. The respondent is given seven reasons for stating zero WTP and is required to choose one main reason for doing so.

Common reasons for identifying protest zeros are: (1) when the respondent shows dissatisfaction toward the mode of financing such as refusing to pay for haze damages that are caused by others; (2) when the respondent believes that it is everyone's responsibility and not just locals' issue; (3) when the respondent thinks that government should pay for it; or (4) when the respondent indicates that more information/time is required to answer the question.

Section 6 of the questionnaire aims to gauge the amount of money the respondent spent on haze adaptation equipment, such as air purifiers and masks, as well as treatments from the negative effects of haze. Sentiments regarding this equipment were also measured on a 5-point Likert scale, with "1" being "Not Effective" to "5" being "Most Effective." Level of outdoor exposure is also recorded based on two categories, one is on occupational needs and another is on leisure activities.

The last section is designed to collect details regarding the respondent's socioeconomic and demographic characteristics such as gender, highest level of education, residential type, and monthly income. These variables are included in a questionnaire survey adopted by Wang et al. (2016), some of which are correlated with one's WTP. Knowing the variables

Table 1. Population and sample distribution

Region	Percentage of population: Actual	Survey	Number of participants
Central	24%	23%	180
West	23%	24%	192
North	21%	21%	164
East	18%	18%	144
North East	14%	14%	113
Total	100%	100%	793

Table 2. Subsamples with different initial bids

Subsample	Sample size	"No" to initial bid	Initial bid	"Yes" to initial bid
Set A	262	12.50	25.00	50.00
Set B	266	25.00	50.00	100.00
Set C	265	50.00	100.00	200.00

that are strongly related to WTP would also allow us to identify explanatory variables that can influence one's WTP.

3.2 Empirical methods

We conducted a CV survey with 793 Singapore citizens and Singapore permanent residents aged 21 years and above between the months of November and December 2017. The participants were randomly selected from five different regions in Singapore (Central, West, North, East, and North East) for face-to-face interviews. Table 1 shows the actual population and sample distribution in the five regions.

This sample size matched Singapore's population profile by gender, age, and ethnic distribution. To ensure the validity of this survey instrument, focus group discussions were held and a pilot study was performed on a group of 25 participants. An open-ended elicitation format asking them about the maximum amount they would be willing to pay is used in the pilot study to obtain the mean WTP, which was then used to determine the starting bids in the actual survey. Three starting bids of S$ 25 (Set A), S$ 50 (Set B) and S$ 100 (Set C) were used. The bid vectors are: [S$ 12.50, S$ 25, S$ 50], [S$ 25, S$ 50, S$ 100] and [S$ 50, S$ 100, S$ 200] and the respective sample sizes of the three different sets are shown in Table 2.

4. Findings

4.1 Summary statistics

Table 3 provides a summary of the sample distribution of socioeconomic variables obtained from the survey. These variables are included in the regression analysis as they may have impact on WTP.

Table 3. Sample distribution of socioeconomic variables

Variable	Distribution	Number	Percentage
Age group, years	21–29	188	23.7%
	30–39	182	23.0%
	40–49	159	20.0%
	50–59	180	22.7%
	60 and above	84	10.6%
Gender	Women	409	51.6%
	Men	384	48.4%
Ethnicity	Chinese	622	78.4%
	Malay	97	12.2%
	Indian	56	7.1%
	Others	18	2.3%
Education	Non-tertiary	286	36.1%
	Diploma and higher	505	63.7%
	N.A.	2	0.2%
Monthly income	Below $S 1,000	197	24.8%
	$ 1,000–$ 1,999	113	14.3%
	$ 2,000–$ 2,999	134	16.9%
	$ 3,000–$ 3,999	111	14.0%
	$ 4,000–$ 4,999	81	10.2%
	$ 5,000–$ 5,999	55	6.9%
	$ 6,000–$ 6,999	23	2.9%
	$ 7,000–$ 9,999	39	4.9%
	S$ 10,000 and above	35	4.4%
	N.A.	5	0.6%
Marital status	Single	333	42.0%
	Married	459	57.9%
	N.A.	1	0.1%
Children	None	357	45.0%
	With children	434	54.7%
	N.A.	2	0.2%
Sole breadwinner	No	655	82.6%
	Yes	138	17.4%
Household size	1–3	225	28.4%
	4–6	540	68.1%
	7 and above	27	3.4%
	N.A.	1	0.1%

Note: *N.A. denotes missing data, wherein the respondent did not provide answers to the corresponding questions. Such observations are excluded from the analysis.*

Comparing the distribution of the survey sample to that of the Singapore population aged 20 years and above (Table 4), it is observed that the sample is representative in terms of gender and ethnicity. Furthermore, the sample closely aligns with the distribution of different age groups, except for a relatively lower representation of individuals aged 60 years and above. This deviation could potentially impact the estimation of WTP, considering that the elderly are particularly vulnerable to the effects of haze and may thus exhibit a higher willingness to pay. However, our subsequent analysis suggests that age is not a significant determinant of WTP.

4.2 Protest bid and validity check

Among the total sample size of 793, to derive the true WTP, we impose two selection criteria to determine whether the WTP responses from the respondents should be included in the estimation of WTP. The first criterion is to ensure that the zero response is indeed a true zero. The second is to make sure that the respondent passes the validity test of

Table 4. Demographic distribution of Singapore population aged 20 years and over

Variable	Distribution	Percentage
Age group, years	20–29	17.5%
	30–39	18.5%
	40–49	19.6%
	50–59	19.6%
	60 and above	24.8%
Gender	Women	51.5%
	Men	48.5%
Ethnicity	Chinese	76.0%
	Malay	12.4%
	Indian	8.5%
	Others	3.0%

Source: *Department of Statistics Singapore, 2017.*

Table 5. Reasons for zero WTP

		WTP1		WTP2	
	Reason for zero WTP	**No**	**%**	**No**	**%**
True zero	I/Our household cannot afford to pay	13	6.2	15	6.2
	I think this problem is not a priority	10	4.7	9	3.7
	I am not interested in this matter	8	3.8	8	3.3
Protest bid	I object to paying for other's actions	42	19.9	52	21.6
	Everyone should pay for this, not just the local people	10	4.7	7	2.9
	The government should pay for this	109	51.7	129	53.5
	I need more information/time to answer this question	19	9.0	21	8.7
Total		211	100.0	241	100.0

having WTP of Adaptation (WTP1) that is no greater than WTP of Eradication (WTP2). This is because the Adaptation program described to respondents does not aim to improve air quality during a haze period and hence the air quality is inferior compared with that under the Eradication program with no haze. Correspondingly, this implies that haze is here to stay under the Adaptation program and the associated welfare should be lower as compared to the welfare derived from the Eradication program. Any respondent who indicates WTP1 (Adaptation) larger than WTP2 (Eradication) is said to have failed the validity test and hence excluded from the estimation of mean WTP.

Respondents who replied "no-no" to both initial and follow-up bids were asked whether they are willing to pay anything at all. Out of the total of 793, 211 respondents gave zero values to WTP1 (26.6 percent of the sample), and 241 respondents gave zero values to WTP2 (30.4 percent of the sample). In addition, reasons concerning respondents' motives behind zero WTP bids are presented in Table 5. Specifically, a zero response is identified as protest if the respondent chooses one of the following four reasons: (1) I object to paying for other's actions; (2) Everyone should pay for this, not just the local people; (3) The government should pay for this; or (4) I need more information/time to answer this question. For WTP for Adaptation (WTP1), 180 (85.3 percent) of the overall zero responses are protest bids, of which 109 (51.7 percent) of the respondents believe that it is the

Table 6. Validity regression result, N = 636

	Linear regression		Probit regression	
	Estimates	Standard errors	Estimates	Standard errors
Knowledge	0.00828	(0.00936)	0.0384	(0.0409)
Attitude	−0.0468	(0.0357)	−0.203	(0.151)
Health concern	−0.0134	(0.0278)	−0.0466	(0.122)
Environmental concern	−0.0279	(0.0253)	−0.122	(0.111)
Air quality rating	0.00655	(0.0194)	0.0220	(0.0855)
Positive forecast	−0.0358**	(0.0172)	−0.149**	(0.0724)
Annoyance	0.0108	(0.0087)	0.0487	(0.0366)
Chronic problem	0.0154	(0.0341)	0.0578	(0.147)
Treatment due to haze	−0.0754*	(0.0389)	−0.296*	(0.159)
Spend on equipment	0.0000	(0.0001)	0.0002	(0.0005)
Occupational exposure	−0.00751	(0.0121)	−0.0291	(0.0518)
Outdoor leisure	0.0309**	(0.0146)	0.137**	(0.0649)
Constant	1.058***	(0.174)	1.895**	(0.760)

Note: *Respondents with both protest zero WTP1 and protest zero WTP2 are excluded. ***Statistically significant at the 1 percent level; **statistically significant at the 5 percent level; *statistically significant at the 10 percent level.*

government's responsibility and hence the government should pay for it. Close to 20 percent of the respondents hold the view that they do not want to pay for other people's actions and 4.7 percent of the respondents insist that everyone should pay for this, not just the local people. Similarly, for WTP for Eradication (WTP2), we see a slightly higher percentage of protest responses of 209 (86.7 percent). Again, 53.3 percent of these protest respondents feel that the government should pay for it. In total, 180 protest WTP1 bids and 209 protest WTP2 bids are excluded in our estimation.

In addition, 98 respondents (12.4 percent of the sample) also failed the validity test because they reported a higher value for WTP1 than for WTP2. Regression analysis was performed to examine which factors are responsible for this failure. The dependent variable is a dummy variable that takes the value of 1 if WTP2 $\geq$ WTP1 and 0 otherwise. As shown in Table 6, positive forecast and treatment are significantly negative while outdoor leisure is significantly positive. It indicates that respondents have higher relative WTP for the haze mitigation program if they are more optimistic about future air quality or if they spend less time on outdoor leisure activities. People who paid for treatment of haze-related health illnesses are also more likely to have higher relative WTP1. The reason for this is that subsidized health care for haze related illnesses is provided in the hypothetical scenario of a haze adaptation program.

4.3 WTP estimation

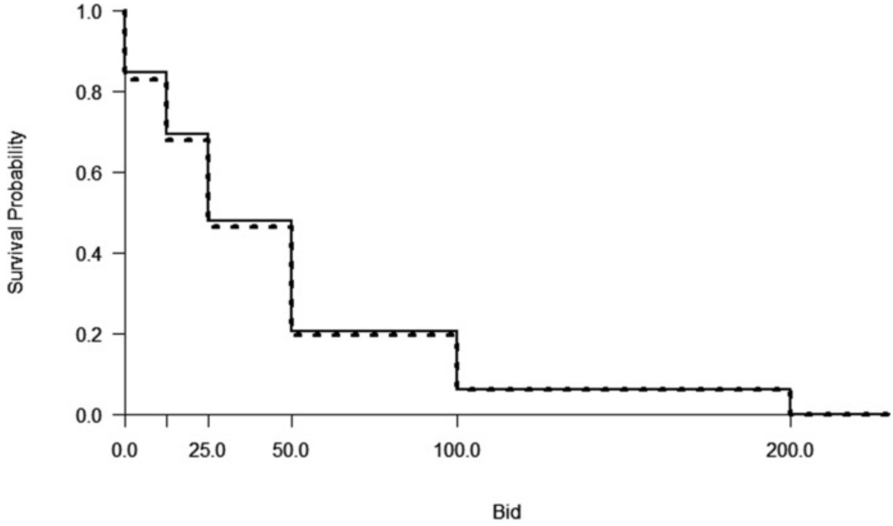
In the estimation of mean WTP, we treat protest zeros properly by truncating the sample to retain true valuation response in the estimation while the protest zeros are removed from the data set. Two approaches are used in estimating the mean WTP of both an adaptive program (WTP1) and a haze eradication program (WTP2). One is the non-parametric method of Kaplan-Meier-Turnbull, and another is estimated using the probit model.

The Kaplan-Meier-Turnbull estimator usually gives a conservative estimate of WTP. This is because the proportion of "yes" responses for each bid value forms a monotonic sequence. For example, it assumes that the probability of a respondent's WTP bid value not used in the surveys is equal to the probability of their WTP for the closest higher value among the bid values by assuming that the higher the bid, the less likely respondents are to say yes, and hence the "proportion of survivors" decreases with the bid levels (Lin et al. 2017). By assuming that the distribution of WTP bids falls at the lowest value of the bid interval, this also conveniently addresses the possible problem of negative WTP, meaning that some people may feel that they should be compensated for an improvement in air quality (Haab and McConnell 1997). The empirical probability estimates of the survival function can be computed by dividing the number of respondents who are willing to pay more than or equal to a bid level, over the number of responses to that bid level. The mean WTP can then be estimated as the area under the probability function by multiplying the Kaplan-Meier-Turnbull estimates with the difference between the WTP bid ranges and summing the results.

Estimating the WTP of an individual and the distribution of WTP in a target population can be done by relying upon parametric assumptions regarding the nature of consumer preferences. For example, segregating the individual's WTP into a non-stochastic bid function based on their observed characteristics and valuation of air quality, and a stochastic component or residual to account for the heterogeneity of unobserved preferences, the functional form of the WTP and distribution of the error term via maximum likelihood estimation can be assumed (Crooker and Herriges 2004). Therefore, the advantage of parametric approaches is that they can account for the relationship of other variables with WTP and the model specification of interest. One approach is to use a double-bounded probit model to estimate WTP where the probabilities of a respondent's WTP lying between an initial bid value and the corresponding second bid value for four cases: Yes-Yes; Yes-No; No-Yes; and No-No can be first calculated. Then, a maximum likelihood function (taking logs and summing probabilities of all four cases) is used to estimate individual WTP coefficient values. Each of the other variables of interest can then be added sequentially into the regression model, subjected to a stepwise likelihood ratio test to ascertain the explanatory power of the collective variables added.

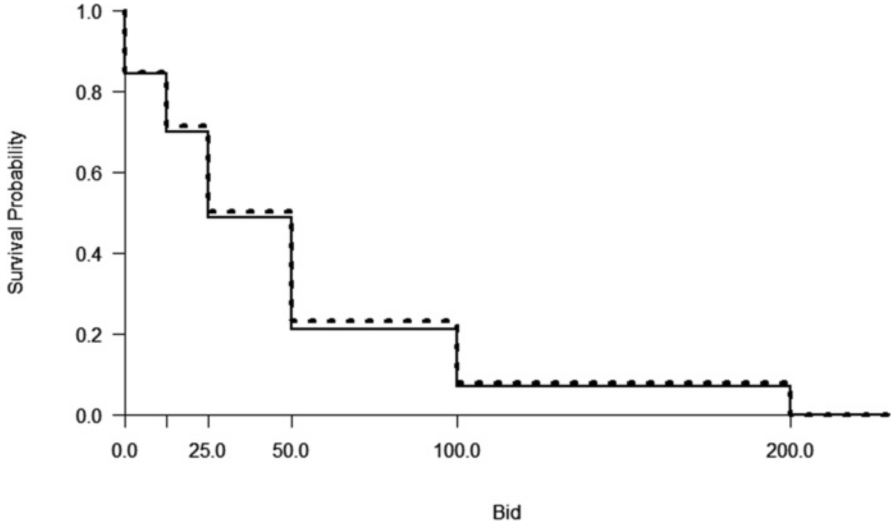
4.3.1 Kaplan-Meier-Turnbull Applying the non-parametric method of Kaplan-Meier-Turnbull, we estimate a mean WTP of S$ 47.75 for the haze adaptation program and S$ 49.10 for the haze eradication program. Upon eliminating non-valid bids, mean WTP1 becomes slightly lower with a value of S$ 46.46 while the mean value for WTP2 increases to S$ 51.66. The presence of non-valid bids, characterized by WTP1 > WTP2, creates an upward bias in the estimation of mean WTP1 and a downward bias in the estimation of mean WTP2. Survival curves for WTP1 and WTP2 are shown in Figures 2 and 3, respectively.

Figure 2. Survival curve for haze adaptation program



Note: *The solid line is estimated with non-valid bids included while the dashed line is estimated with non-valid bids excluded.*

Figure 3. Survival curve for haze mitigation program



Note: *The solid line is estimated with non-valid bids included while the dashed line is estimated with non-valid bids excluded.*

Table 7. WTP probit regression results

	WTP1 (Adaptation)				WTP2 (Eradication)			
	Including non-valid		Excluding non-valid		Including non-valid		Excluding non-valid	
	Estimates	Standard errors	Estimates	Standard errors	Estimates	Standard errors	Estimates	Standard errors
Knowledge	−0.670	(1.866)	0.0382	(1.987)	1.299	(1.935)	1.032	(2.058)
Attitude	−3.274	(6.945)	5.239	(7.624)	−1.023	(7.377)	1.357	(7.891)
Health concern	2.106	(5.468)	3.696	(5.837)	5.362	(5.693)	6.739	(6.068)
Environmental concern	19.04***	(5.056)	20.95***	(5.399)	11.40**	(5.259)	13.50**	(5.526)
Air quality rating	6.631*	(3.782)	5.376	(4.047)	9.410**	(3.993)	10.29**	(4.208)
Positive forecast	−1.629	(3.397)	−1.780	(3.756)	−2.947	(3.632)	−1.919	(3.944)
Annoyance	−0.898	(1.725)	−1.691	(1.913)	−0.815	(1.871)	−1.880	(2.004)
Chronic problem	15.99**	(6.634)	19.13***	(7.157)	19.09***	(7.088)	17.71**	(7.531)
Treatment due to haze	−0.534	(7.629)	2.192	(8.529)	1.929	(8.151)	5.237	(8.804)
Spend on equipment	0.00219	(0.0233)	−0.00816	(0.0244)	−0.00282	(0.0241)	−0.00504	(0.0250)
Occupational exposure	−4.172*	(2.402)	−4.035	(2.641)	−2.735	(2.521)	−2.729	(2.728)
Outdoor leisure	−0.517	(2.892)	−0.336	(3.153)	0.595	(3.089)	−0.558	(3.309)
Age	−0.424	(0.331)	−0.520	(0.350)	−0.212	(0.344)	−0.251	(0.365)
Gender	6.463	(5.880)	8.523	(6.416)	9.898	(6.348)	9.809	(6.785)
Chinese	10.23	(7.200)	15.58*	(8.038)	20.22***	(7.796)	23.05***	(8.388)
Degree	6.155	(7.059)	8.434	(7.542)	5.306	(7.466)	5.806	(7.947)
Income	0.00447***	(0.00132)	0.00407***	(0.00146)	0.00268*	(0.00140)	0.00367**	(0.00154)
Marriage	5.044	(11.02)	5.325	(11.52)	2.351	(11.58)	4.071	(12.00)
Children	−1.386	(11.99)	2.183	(12.56)	1.045	(12.52)	−0.00728	(13.03)
Sole breadwinner	−2.175	(8.428)	−7.707	(9.119)	−8.574	(8.798)	−9.410	(9.441)
Household size	1.710	(2.335)	3.540	(2.634)	−0.269	(2.550)	1.412	(2.759)
Constant	−36.60	(35.90)	−84.01**	(38.26)	−53.22	(38.09)	−75.53*	(40.61)
Observations	606		509		579		528	
Log likelihood	−876.20		−727.60		−845.68		−767.90	
χ^2 *p*-value	0.0000		0.0000		0.0004		0.0001	

Note: *Observations with missing socioeconomic variables are dropped in the regression. ***Statistically significant at the 1 percent level; **statistically significant at the 5 percent level; *statistically significant at the 10 percent level.*

Most respondents, approximately 92 to 94 percent of the sample, are estimated to have a WTP of $100 or less for either program.

4.3.2 Probit model Double-bounded probit regressions are conducted to elicit the determinants of WTP. The regression results in Table 7 show the relationships between explanatory variables and WTP. De Pretto et al. (2015) found that higher knowledge shapes more negative attitudes toward haze, which translates to a higher likelihood of engaging in protective behavior. Likewise, EPRI et al. (2006) found that revealed attitudes of respondents were consistent with there being a component of existence value in their responses. However, in our study, we find that knowledge, attitude, health concern, optimism about future air quality, and annoyance level do not affect the value of WTP.

In contrast, environmental concerns and chronic health problems are significant predictors of WTP. Respondents are willing to pay a higher amount if they have more concerns for the environment and if they or their family members suffer from chronic breathing problems. All else being equal, a one-point increase on the Likert scale measuring environmental concern corresponds to an average increase in WTP1 of S$ 20.95 and an increase in WTP2 of S$ 13.50. Individuals who reported having a chronic health problem, or have family members with such conditions, exhibit a greater WTP of S$ 19.13 for the adaptation program and S$ 17.71 for the eradication program. These findings, in a way, are consistent with De Pretto et al. (2015), who ranked concerns on specific types of haze impacts and showed that health followed by the impact on environment are of the highest concern.

Additionally, our findings also show that those who gave a higher rating for air quality are also more willing to pay a higher amount, especially for the haze eradication program as they want to maintain the clean air environment. On average, an increase of one Likert point in air quality rating is associated with an increase of S$ 10.29 in WTP2, ceteris paribus.

To our surprise, people with higher levels of outdoor exposure for occupation needs are less willing to pay for the haze adaptation program. An explanation is that individuals who need to work outdoors are not interested in the option of work-from-home provided in the hypothetical scenario. However, this relationship is statistically insignificant when invalid bids are excluded from the regression.

Among various socioeconomic variables, income is found to be a significant predictor of WTP. Given that respondents are asked to indicate their income brackets, we use the median value within each bracket as the representative value for the income variable. For the highest income bracket (≥ S$ 10,000), where the median value is not available, the minimum value is used instead. Higher income is associated with higher WTP, which is consistent with past literature, such as studies by Lin et al. (2017), Wang et al. (2016), Sun et al. (2016) and Wang and Mullahy (2006). A S$ 1,000 increase in income leads to an average increase of S$ 4.07 in WTP1 and an increase of S$ 3.67 in WTP2, holding other factors constant. This is intuitive as respondents have greater financial ability to pay more, although Singapore's progressive income tax rates could potentially weaken the correlation. Respondents of Chinese descent are also found to have significantly higher WTP compared with respondents of other ethnicities. They are willing to pay an average additional S$ 15.58 for the adaptation program and S$ 23.05 for the eradication program.

The effect of age on WTP is not so clear at the outset, as older respondents may appear to be either more conservative with their income or willing to pay more as they are more susceptible to illnesses as they age. Wang and Mullahy (2006) found that age is negatively correlated with the probability of positive WTP and a positive but insignificant relationship with WTP. We find a negative but insignificant relationship between age and WTP. Unlike Lin et al. (2017) and Wang et al. (2006), who found that higher educational level has been associated with higher WTP as respondents are more likely to understand the ill effects of the haze better and the need to act, we find no significant relationship between education and WTP. Wang et al. (2016) found that men are more willing to contribute to haze management measures, which may imply the presence of a gender income disparity, while

Table 8. Summary of WTP estimation

Kaplan-Meier-Turnbull			
Adaptation (WTP1)		**Eradication (WTP2)**	
Including non-valid	**Excluding non-valid**	**Including non-valid**	**Excluding non-valid**
S$ 47.75	S$ 46.46	S$ 49.10	S$ 51.66
Probit model			
Adaptation (WTP1)		**Eradication (WTP2)**	
Including non-valid	**Excluding non-valid**	**Including non-valid**	**Excluding non-valid**
S$ 62.18	S$ 60.06	S$ 63.69	S$ 66.76

Wang and Mullahy (2006) found the possibility that women have a higher WTP albeit the gender coefficient being insignificant. We find no such impact of gender on WTP. Other socioeconomic characteristics are also found to have no impact on WTP.

Overall, the main determinants of WTP include environmental concern, air quality rating, chronic health problem, income, and Chinese ethnicity. Applying the result from a probit model, we estimate a mean WTP1 of S$ 62.18 and a mean WTP2 of S$ 63.69. Excluding non-valid bids, mean WTP1 is reduced to S$ 60.06 while mean WTP2 is increased to S$ 66.76. These estimated values are higher than those of the non-parametric model. Table 8 provides a summary of estimated WTP for both non-parametric and parametric methods.

The total annual national WTP can be estimated as $N \times WTP_{mean}$, where N is the unit of population. As the total number of Singapore residents aged 20 years and above is 3,138,342 in 2017, the aggregate annual WTP is S$ 188.5 million and S$ 209.5 million for adaptation and eradication, respectively. In comparison to the findings of Lin et al. (2017), our estimates are lower. Several factors contribute to this discrepancy. First, in the hypothetical question presented to respondents, we assume a one-month duration for the occurrence of haze and ask respondents to identify their WTP for both adaptation and eradication scenarios. However, the actual duration of the 2015 haze in Singapore spanned approximately two months. In contrast, Lin et al. (2017) asked for WTP under the condition of the Singapore government ensuring year-round good air quality, with the PSI remaining within the range of 0–50. Thus, it is reasonable that our estimates are lower than theirs. Secondly, their sample exhibits an overrepresentation of individuals from younger age groups and those with higher levels of education. Our analysis reveals that age has a negative impact on WTP, whereas education has a positive influence, albeit statistically insignificant. Consequently, it is plausible that their estimate is subject to an upward bias.

5. Policy implications and conclusion

Based on historical data and current development and efforts put in place to fight against haze, it is reasonable for one to expect haze episodes in subsequent years. The burning usually peaks from June to September, when Indonesia experiences a dry season and many farmers take advantage of the dry conditions to clear land for palm oil and pulp and paper plantations using the slash-and-burn method. The problem has become more severe in recent years when increasingly more land has been cleared for expanding plantations for the profitable palm oil trade. Strikingly, for the 2015 haze outbreak, according to Indonesia, it was not just small-scale farmers who use the cheaper slash-and-burn method. Many of these fires are started by large companies that want to plant oil palm plantations. Indonesia is not entirely to blame, as some of the large companies accused of illegal burning have Malaysian and Singaporean investors. In Singapore, there were suggestions of holding Singapore firms accountable for the pollution and calls for consumers to boycott haze-linked products. However, such recommendations are debatable, especially when there are no disclosures of land ownership from Indonesia. In addition, if other countries do not penalize their own culprit firms to a similar magnitude, then Singapore's firms will be made worse off in relative terms, hindering their competition in the global market. Additionally, these suggestions are unlikely to bring any measure of success in reducing the burning partly because Singapore's consumption of paper or palm oil products only constitutes a small portion of the global market demand.

Instead of pointing our fingers at polluters, we should focus on how we could escape this recurring challenge. The victim-pay principle proposed by Quah and Moeller (2018), of paying the polluter to fund the appropriate land-clearing agricultural equipment, financial incentives, and disincentives to small landholders to stop slash-and-burn practices, may be theoretically appealing but practically not feasible. This conclusion is obtained from the survey of 793 respondents, out of which more than 20 percent indicated objection to paying for other's actions. Given the limited options available for Singapore, adapting to haze becomes a solution, though not the first best, while we continue to search for practical solutions. Findings from the contingent valuation survey suggest that Singapore residents in general are willing to pay between S$ 46.46 and S$ 60.06 for a haze adaptation program that reduces the local impacts of haze by giving out timely information on air quality, providing face masks and subsidizing health care, and designing a work-from-home/study-from-home scheme during the haze period. It remains unclear from the survey on how optimistic residents are toward eradicating haze. However, given the mean WTP of a haze eradication program of S$ 51.66 from the Kaplan-Meier-Turnbull estimation and S$ 66.76 from the probit regression suggests that Singapore residents continue to value government's effort to derive solutions to resolve the haze crisis that recurs intermittently.

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