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Singapore's willingness to pay for mitigation of transboundary forest-fire haze from Indonesia

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Abstract

Haze pollution over the past four decades in Southeast Asia is mainly a result of forest and peatland fires in Indonesia. The economic impacts of haze include adverse health effects and disruption to transport and tourism. Previous studies have used a variety of approaches to assess the economic impacts of haze and the forest fires more generally. But no study has used contingent valuation to assess non-market impacts of haze on individuals. Here we apply contingent valuation to estimate impacts of haze on Singapore, one of most severely affected countries. We used a double-bounded dichotomous-choice survey design and the Kaplan-Meier-Turnbull method to infer the distribution of Singaporeans' willingness to pay (WTP) for haze mitigation. Our estimate of mean individual WTP was 0.97% of annual income ($n = 390$). To calculate total national WTP, we stratified by income, the demographic variable most strongly related to individual WTP. The total WTP estimate was $643.5 million per year (95% CI [$527.7 million, $765.0 million]). This estimate is comparable in magnitude to previously estimated impacts of Indonesia's fires and also to the estimated costs of peatland protection and restoration. We recommend that our results be incorporated into future cost–benefit analyses of the fires and mitigation strategies.

Introduction

Rapid land use change and El Niño–Southern Oscillations have resulted in recurring fires in Southeast Asia in recent decades (Heil and Goldammer 2001). Most fires are initially lit deliberately, albeit illegally, to clear land for agriculture. Frequently the fires then ignite underlying peat soils (Saharjo 2015). The peat fires, in particular, release large amounts of carbon dioxide, along with aerosols and toxic particulates that are collectively known as 'haze'. The economic and environmental impacts of these fires are numerous. Carbon dioxide emissions contribute to global climate change. The biodiversity impacts of burning species-rich forests and subjecting them to prolonged smoke exposure are also large, but less well understood (Posa et al 2011, Chisholm et al 2016). Regionally, the most prominent impacts are those associated with the haze (Tacconi 2016).

Haze consists of small airborne particles generated from fires, 60%–90% of them originating from peatlands, and comprised of over 100 compounds (Page et al 2002, Reddington et al 2014, Gaveau et al 2014). Haze pollution has been a sporadic problem in Southeast Asia over the past 20 years (Heil and Goldammer 2001, Kunii et al 2002, Hayasaka et al 2014, Putra et al 2008). Its economic impacts are felt most strongly in Indonesia and neighbouring Singapore and Malaysia, but also extend to Vietnam, Thailand and the Philippines (Nichol 1998, Chisholm et al 2016, Lee et al 2016). Health effects of haze include respiratory ailments and exacerbation of existing heart and lung conditions (Kunii et al 2002, Sastry 2002, Jayachandran 2009). Other economic impacts include disruption to transport and tourism (Lee et al 2016, Quah 2002). In Singapore, the major 1997 haze event was the first to catch the public's attention, with the 24 hour Pollution Standards Index (PSI) peaking at 138, indicating 'Unhealthy' air quality, and hospital admissions for haze-related conditions increasing by 30% (Emmanuel 2000). The 2013 haze event saw an all-time record 24 h

PSI of 226, indicating 'Very Unhealthy' air quality (Gaveau *et al* 2014). The 2013 event also witnessed a record three-hour PSI of 401, well above the 'Hazardous' air quality threshold of 300 (Betha *et al* 2014). The year 2015 witnessed the longest haze event on record, coinciding with the El Niño fires in Indonesia and lasting three months (Tan 2016). In Singapore, the worst air quality of 2015 was recorded on 25 September, with the 24 h PSI peaking at 322 and the 3 h PSI peaking at 341, both in the 'Hazardous' range.

There have been multiple attempts to deal with the region's transboundary haze pollution. The 2002 ASEAN Agreement on Transboundary Haze Pollution was, as of 2014, signed by all ten ASEAN countries (Tan 2005, Lee *et al* 2016). In the two decades prior to 2007, over $30 million was invested in 40 forest fire deterrence projects (Tacconi *et al* 2007). Neighbouring countries have offered Indonesia aid for monitoring and control of forest fires, but the Indonesian government has been reluctant to accept this aid (Lee *et al* 2016). The Indonesian government has itself moved towards better peatland management by enacting legislation to protect the peatlands and establishing of the Peatland Restoration Agency. These efforts centre around the restoration of two million hectares of peatlands and development of sustainable peatland agriculture (Wijedasa *et al* 2016). In Singapore, the Transboundary Haze Pollution Act 2014 gave the national government the power to take legal action against companies whose overseas operations cause haze in Singapore. During the 2015 event, the Singapore Environmental Council suspended the Green Label for environmental sustainability given to several haze-linked companies, leading to the removal of these companies' products from some supermarket shelves and increased public awareness of the links between consumer goods and haze (Wijedasa *et al* 2015). This has also spurred community-driven projects such as the People's Movement to Stop Haze, which attempts to spur communities into taking direct action. Despite all these efforts, haze remains a persistent threat (Yong and Peh 2016).
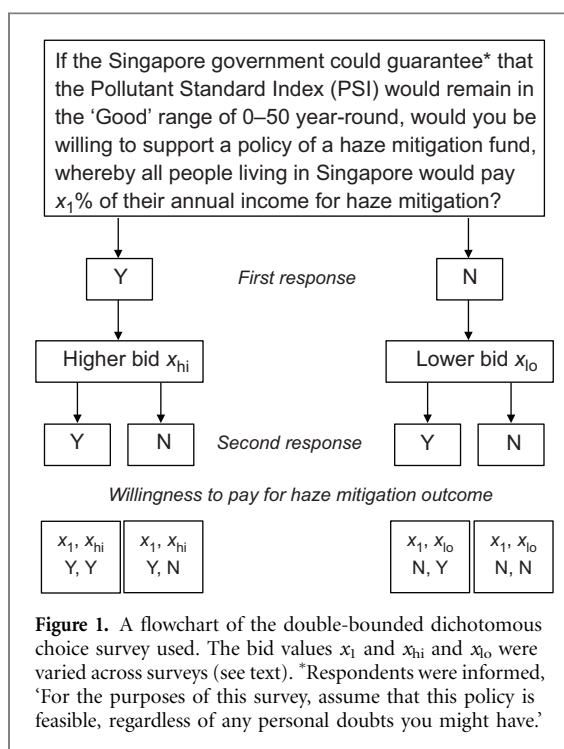
Long-term solutions to the transboundary haze problem first require estimates of the costs of haze. The traditional perception of air as a public good and the norm of excluding public goods in economic development measures leads to an illusory picture of the benefits of agricultural practices in Indonesia, particularly palm oil (Ramdani and Hino 2013, Schrier-Uijl *et al* 2013, Sumarga and Hein 2016). It is hard to measure the negative environmental externalities of haze pollution in Southeast Asia, because the costs are diffuse in time and space (Chisholm *et al* 2016). This knowledge gap makes it difficult to quantify the overall costs of forest fires, and to motivate political action to solve the problem.

The economic impact of haze pollution in Singapore has previously been estimated with cost–benefit analysis. For example, the 1997 haze incident caused an estimated $163.5–$286.2 million in total damage costs, including impacts on health, outdoor activities, tourism and visibility (Quah 2002). Such figures may, however, be an underestimate because they exclude impacts that are difficult to infer from economic data, such as non-hospitalisable health effects and reductions in the quality of life of citizens. Thus, to obtain a more comprehensive picture of haze impacts in Singapore there is a need for non-market valuation methods that can capture these effects (Carlsson and Johansson-Stenman 2000). There are three commonly used such methods: hedonic pricing, the travel cost method and contingent valuation (Mishan and Quah 2007). Hedonic pricing infers the value of non-market goods from the prices of market goods, e.g. the value of nearby parkland can be inferred from correlations with house prices. The travel cost method infers the value of a non-market good, e.g. a national park, from the costs incurred by individuals travelling to obtain the good. Neither of these methods would be effective for estimating the costs of haze in Singapore, because both rely on spatial variation in the non-market good, and there is little variation in air quality across Singapore. The third method, contingent valuation, is a survey-based evaluation method that explicitly asks people's maximum willingness level to pay for environmental goods and services (Cummings *et al* 1986) and is suitable for estimating haze impacts (Glover and Jessup 1999).

In this study, we aim to estimate the economic impacts of haze on Singapore through contingent valuation by asking Singaporeans their willingness to pay (WTP) for haze-free air. Theoretically, the amount of money respondents agree to pay for haze-free air should be equal to the welfare they obtain from clean air (Mishan and Quah 2007), which in turn should be equal to the costs imposed on them by haze. Contingent valuation can capture costs of haze that are not captured with market-based valuation methods and can thereby contribute to a holistic assessment of haze impacts. Our specific objectives are (1) to assess WTP for haze mitigation among Singaporeans; (2) to explore socio-economic factors shaping people's level of WTP for haze mitigation; and (3) to estimate a total annual national monetary value of WTP for haze mitigation.

Methods

Throughout this paper we provide currency values in US dollars, except when referring to salaries, which are given in Singapore dollars (SGD) as in our surveys. These figures are presented suffixed with 'SGD'. In conversions, we use an exchange rate of US$1.00 = 1.37 SGD, the exchange rate in the year of the surveys (2015).

Figure 1. A flowchart of the double-bounded dichotomous choice survey used. The bid values x_1 and x_{hi} and x_{lo} were varied across surveys (see text). *Respondents were informed, 'For the purposes of this survey, assume that this policy is feasible, regardless of any personal doubts you might have.'

Table 1. Six sets of bidding values used in the survey.

	1	2	3	4	5	6
First bid (x_1)	0.10%	0.25%	0.50%	1.00%	2.00%	4.00%
Second bid (x_{hi})	0.25%	0.50%	1.00%	2.00%	4.00%	5.00%
Second bid (x_{lo})	0.05%	0.10%	0.25%	0.50%	1.00%	2.00%

(iv) First bid: Ask the respondent to choose between 'Yes' and 'No' when asked whether he or she would support a policy whereby all people living in Singapore would pay a specific percentage x_1 of their incomes to mitigate haze for one year. The percentage value in each survey was randomly chosen from six possible values previously established as plausible during a pilot survey (table 1). Respondents were also presented with a conversion table from annual income to a percentage x_1 of annual income to facilitate visualization.

(v) Second bid: If the respondent answered 'Yes' to the first bid, ask him or her to respond to the same question again but with a higher bid value x_{hi}. If the respondent answered 'No' to the first bid, ask him or her to respond to the same question again but with a lower bid value x_{lo} (table 1).

(vi) Ask the respondent to provide socio-economic information including income level, age, marital status and number of children (see appendix A for complete questionnaire).

The data gleaned from each survey thus comprised the two bid values, x_1 followed by x_{lo} or x_{hi}, two bid outcomes ('Yes, Yes', 'Yes, No', 'No, Yes' or 'No, No'), and the demographic information.

The questionnaire was implemented in Google Docs and presented to respondents on an iPad. The surveys were conducted over a three-month period, from November 2015 to February 2016, in public areas, including residential and business districts. To cover a broad spectrum of Singaporeans we surveyed across all five regions of Singapore defined by the Urban Redevelopment Authority 2014 (East, Central, North, West, North East). Target respondents were citizens or legal residents of Singaporean at least 21 years of age. A total of 196 hours was spent on face-to-face interactions with respondents or potential respondents. The questionnaire was also posted on the internet to solicit online responses and a link to the questionnaire was publicised in the national media (Tan 2015).

Survey design and execution
Our contingent-valuation survey used a double-bounded dichotomous choice design, in which a respondent is presented with two successive bid amounts and required to respond 'yes' or 'no' to each. Dichotomous choice surveys elicit more accurate and consistent responses than open-ended surveys (Carson and Hanemann 2005), and double-bounded dichotomous choice surveys are statistically more efficient than single-bounded ones (Hanemann *et al* 1991, Carson 1985). The survey asked respondents to say 'yes' or 'no' to a hypothetical policy of a mandatory haze mitigation tax, whereby each Singaporean resident would pay a fixed fraction of his or her annual income to guarantee no haze for a year. The questions were worded to be realistic and tangible, in the sense that they described a hypothetical government policy that respondents could visualise. The time frame in the questions was one year to make it easier for respondents to imagine their WTP by associating a potential payment with their annual income for the next year.

The survey protocol was as follows (figure 1 illustrates steps (iv) and (v)):

(i) Approach the *k*th passerby, where *k* is a random integer between 1 and 10 drawn independently for each survey.

(ii) Obtain verbal consent from the respondent prior to the survey.

(iii) Present the respondent with a short introductory paragraph (see appendix A) briefly summarizing the haze situation in Singapore and its health and economic impacts.

Statistical analysis
We used the Kaplan-Meier-Turnbull method (Carson and Hanemann 2005), henceforth referred to simply as the Turnbull method, to estimate percentage WTP from the double-bounded dichotomous-choice survey results. The Turnbull method is standard for

Table 2. Summary of socio-economic data of onsite respondents.

Demographic variable	Distribution	Onsite respondents		Online respondents	
		Number	%	Number	%
Gender[a]	Female	184	47.2	93	64.1
	Male	206	52.8	52	35.9
Age	21–29	100	25.6	86	58.9
	30–39	128	32.8	34	23.3
	40–49	69	17.7	13	8.9
	50–59	59	15.1	7	4.8
	60 and above	34	8.7	6	4.1
Education Level	Less than high school	47	12.1	0	0.0
	High school diploma	139	35.6	26	17.8
	Undergraduate degree	183	46.9	92	63.0
	Graduate degree	21	5.4	18	12.3
Gross Monthly income	No income	41	10.5	10	6.8
	<2 000 SGD	68	17.4	47	32.2
	2 000–3 999 SGD	113	29.0	43	29.5
	4 000–5 999 SGD	102	26.2	27	18.5
	6 000–7 999 SGD	45	11.5	10	6.8
	8 000–9 999 SGD	7	1.8	0	0.0
	≥10 000 SGD	14	3.6	9	6.2
Number of children under 18	0	241	61.8	115	78.8
	1	78	20.0	13	8.9
	2	59	15.1	13	8.9
	3 or more	12	3.1	5	3.4
Number of hours spent outdoor per day	0–2 h	125	32.1	47	32.2
	2.5–4 h	207	53.1	54	37.0
	4.5–6 h	46	11.8	25	17.1
	>6 h	12	3.1	20	13.7
Marital status	Married	215	55.1	46	31.5
	Single	175	44.9	100	68.5

[a] One online respondent did not indicate his or her gender

dichotomous-choice contingent valuation data and gives a conservative estimate of WTP, because it assumes that the probability of a respondent saying 'Yes' to a bid value not used in the surveys is equal to the probability of saying 'Yes' to the closest higher value among the bid values actually used. For example, to estimate the responses to a 3% bid, a value not used in our surveys (table 1), the Turnbull method assumes the probability of a respondent saying 'Yes' to a 3% tax is equal to the probability of a respondent saying 'Yes' to a 4% tax (the closest higher value to 3% in table 1). We used an implementation of the Turnbull method in R (package DCchoice). We also applied the Turnbull method to estimate WTP separately for each level of each demographic variable. We estimated 95% confidence intervals on each WTP estimate by bootstrap resampling the survey data 999 times.

We tested for statistically significant relationships between demographic parameters and estimated WTP (computed from the Turnbull method) using a randomisation approach. For each ordered variable, the Spearman correlation between the variable and estimated WTP was compared to a null distribution obtained by randomising the survey data with respect to the variable 9999 times, and a corresponding

p-value was calculated by comparing the observed Spearman correlation to the null distribution. For each unordered variable, a similar approach was used but with the test statistic being the variance of WTP estimates across categories (variables with >2 categories) or the difference in mean (binary variables).

To estimate total annual WTP for haze mitigation we first stratified the data by income bracket, because income bracket was the demographic variable most strongly related to WTP (see Results). We then used the following formula:

$$\text{WTP} = \sum_{i=1}^{k} I_i w_i N_i \qquad (1)$$

Here I_i is the median income for income bracket i (table 2), w_i is the percentage WTP for income bracket i (as estimated from the Turnbull method), and N_i is the number of working Singapore residents in income bracket i (Ministry of Manpower 2016). Income data for Singapore were available at a resolution of $k = 16$ income brackets whereas the surveys used only seven income brackets. Thus some values of w_i for consecutive i are equal to each other in equation (1). Median incomes in each bracket were used
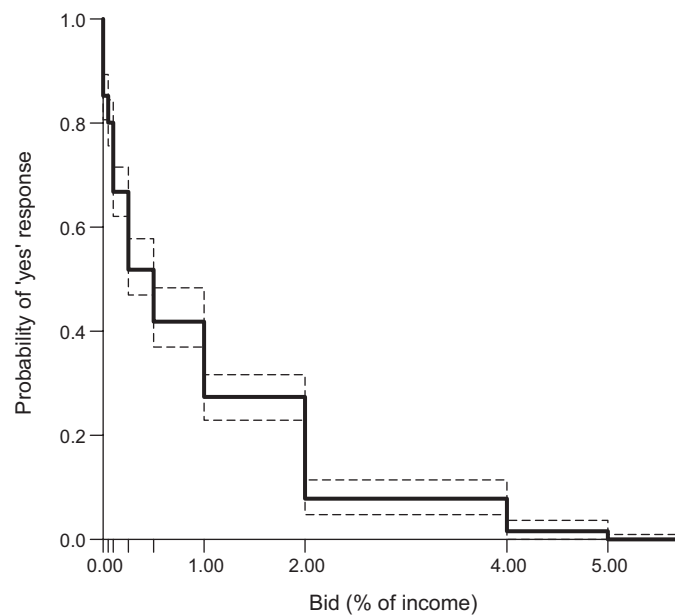
Figure 2. Estimated survival curve for the onsite surveys. The horizontal axis shows bid values as a percentage of annual income; the vertical axis shows the estimated probability of a 'Yes' response (bold lines) with 95% confidence intervals (dashed lines).

Table 3. Estimation of total WTP from onsite surveys stratifying by income levels (all dollar figures in SGD).

Monthly income (SGD)	Median monthly income (SGD)[a]	Number of working residents (thousands)	Estimated percentage WTP	Estimated total annual WTP (SGD)
Under 500	250	47.0	1.20%	1.7 m
500–999	750	125.9	1.20%	13.5 m
1 000–1 499	1 250	234.5	1.20%	42.1 m
1 500–1 999	1 750	203.9	1.20%	51.2 m
2 000–2 499	2 250	205.8	1.09%	60.5 m
2 500–2 999	2 750	164.3	1.09%	59.0 m
3 000–3 999	3 500	294.4	1.09%	134.5 m
4 000–4 999	4 500	194.7	0.85%	89.4 m
5 000–5 999	5 500	157.2	0.85%	88.2 m
6 000–6 999	6 500	94.8	0.58%	43.1 m
7 000–7 999	7 500	72.2	0.58%	37.8 m
8 000–8 999	8 500	59.1	0.58%	34.9 m
9 000–9 999	9 500	40.0	0.58%	26.4 m
10 000–10 999	10 500	40.7	0.70%	35.9 m
11 000–11 999	11 500	23.7	0.70%	22.9 m
≥12 000	12 000	139.5	0.70%	140.5 m
Estimated total national annual WTP (SGD)				**881.6 m**
Estimated total national annual WTP ($)				**$648.2 m**

[a] For the highest income bracket, the minimum income is used instead of the median (see text).

because data on mean incomes was unavailable; this should have little effect on the results because the income brackets are narrow ($\leq 1\,000$ SGD, except for the highest bracket). For the highest income bracket ($\geq 12\,000$ SGD = \$8,759 per month), the median was not known and I_i was instead set at the minimum (i.e. 12 000 SGD); this makes the total WTP estimate conservative.

Results

From the 390 onsite responses and the Turnbull method, we estimated that Singaporeans on average

were willing to support an income tax of 0.97% (95% CI [0.84%, 1.09%]) to guarantee no haze for a year (figure 2). The estimated WTP from the 146 online responses was higher at 1.37% (95% CI [1.06%, 1.69%]).

The onsite respondents were split almost evenly between male and female and spanned a range of age groups, income groups, and other demographic traits (table 2). The percentage WTP was lower for high-income groups than for low-income groups (table 3), although this difference was not statistically significant at the 0.05 threshold ($p = 0.08$). Percentage WTP increased with educational level (appendix B), rising from 0.87% for individuals with less than a high

school diploma to 1.28% for individuals with a post-graduate degree, but this difference was also not statistically significant ($p = 0.15$). The relationships between WTP and other demographic factors were weaker and also not statistically significant (Appendix B). The demographic profile of online respondents was different to that of onsite respondents. Relative to onsite respondents, online respondents were more likely to be female, well educated, young, single, and childless (table 2).

Our estimate of total WTP for the whole of Singapore, based on the onsite responses and stratifying by income brackets, was $643.5 million per year (95% CI [$527.7 million, $765.0 million]) (table 3). Without stratifying by income, the estimate of total WTP is 17% higher at $750.4 million per year. We based our total WTP estimate only on onsite responses because the demographic profile of onsite respondents is closer to that of Singapore as a whole than is that of online respondents. If both onsite and online respondents are included, the estimate of total WTP is 35% higher at $866.2 million (95% CI [$652.8 million, $1107.7 million]).

Discussion

Haze resulting from regional forest and peat fires driven by land-use change is an ongoing environmental problem in Southeast Asia. The broad environmental, social and economic impacts are felt across several countries. Singapore, the economic powerhouse of the region, feels these effects acutely because of its proximity to fire-prone regions in Indonesia and Malaysia, its clean air in non-haze periods, and its reliance on tourism and service industries. In this study, we sought to evaluate the impact of haze on Singapore in monetary terms using the contingent valuation method. Although there are well-known limitations of this method (Carson and Hanemann 2005), our results in conjunction with other economic studies of the haze problem can help to inform the surrounding policy debate.

Level of willingness to pay for haze mitigation in Singapore

We estimated that Singaporeans are willing to sacrifice 0.97% of their annual income for haze-free air year round (figure 2). To give context, the median annual salary in Singapore in 2015 was roughly $35 000 (including retirement fund contributions) and per-capita GDP was $55 000. Our results indicate that Singaporeans experience sufficiently negative impacts of air pollution on their day-to-day life or personal health during haze periods that they are willing to trade-off personal financial gain for improvements in air quality. The estimate of total WTP, based on the onsite survey data, was $643.5 million per year. Online surveys yielded an estimate of WTP that was about 40% higher than those of the onsite surveys, but we considered this figure to be unreliable because of the unusual demographic profile of online respondents (table 2). Interestingly, though, this result ran against our prior expectation that onsite surveys would elicit higher WTP (Bowling 2005).

Our estimate of WTP can be compared to previous estimates of haze impacts on Singapore. The total impacts of the major 1997 haze event on Singapore were estimated at $163.5–286.2 million (Quah 2002, Quah 1999) (0.18%–0.32% of Singapore's GDP at the time). About 98% of these damages were impacts to tourism and loss of visibility and views, with minor contributions from impacts on health and recreation. A subsequent independent analysis estimated 1997 haze impacts on Singapore's health, tourism and aviation industries at $69.3–78.8 million (Glover and Jessup 1999) (0.08%–0.09% of GDP), with about 80% of the costs attributable to tourism losses. A preliminary estimate of impacts of the 2015 haze event by Singapore's Ministry of Environment and Water Resources put the total cost at $510 million (0.17% of GDP).

These previous studies mostly relied on market-based valuation methods (Quah 1999, Glover and Jessup 1999). Our methods and theirs therefore capture a distinct but overlapping set of impacts. Both sets of methods, for example, can account for costs associated with health conditions that require medical care. But whereas their methods attribute the vast majority of costs to tourism impacts, ours likely underestimates tourism losses: most Singaporeans have little direct interaction with the tourism industry and there is little reason to think they consider it when weighing their WTP. Conversely, our contingent-valuation method does provide more comprehensive estimates of health and recreational impacts than methods based on economic data: minor health problems such as coughs and irritations, the inconvenience of wearing a face mask, and other haze impacts are keenly felt by the individual but difficult to detect with market-based methods.

Caveats

Our estimate of Singaporeans' WTP for haze mitigation is conservative insofar as it is calculated from survey data using the Turnbull method (Carson and Hanemann 2005). But there may be positive biases in the survey data themselves. While contingent valuation is frequently used for evaluating non-market goods (Mishan and Quah 2007), the method has received criticism because results can be unduly influenced by survey design and how the questions are drafted (Mitchell and Carson 1989). Particular concerns are scope insensitivity, whereby respondents' WTP can be unrelated to the quantity of a good offered, and a 'social desirability bias', whereby face-to-face responses reflect social norms associated with protecting the environment more than true WTP

(Bowling 2005). By phrasing our survey question as a tangible good (haze-free air for one year) that Singapore residents could easily visualise and relate to, and by emphasising the effects on Singaporeans rather than the broader environmental impacts of the forest fires, we hoped to minimise these positive biases.

An additional positive bias may arise from the fact that our surveys were (by happenstance rather than design) carried out shortly after the 2015 haze event—one of the worst such episodes in Singapore's history. This event was likely prominent in the minds of our respondents when they stated their WTP for haze mitigation. The WTP for haze mitigation in years without severe haze may be lower than estimated here; on the other hand, WTP for haze mitigation during a haze period itself may be even higher than our estimate. Future studies could carry out surveys year-round in both haze and non-haze years to get a more comprehensive picture of Singaporeans' long-term WTP for clean air.

A further caveat associated with the survey design is that, due to the nature of the sampling process, there are particular groups that were difficult to include, such as people with a little education background and high-income earners. To people with little educational background, i.e. the 29.1% of the population with less than secondary educational level, it is sometimes difficult to explain the haze problem and help them understand the questions thoroughly. Thus, their responses might not truly reflect their real thoughts and opinions. The high-income earners, i.e. those towards the upper end of our top income bracket listed in the surveys ($\geq$ 10 000 SGD ($7 299) per month), may be difficult to find in surveys in public places as they tend to have cars as their mode of transportation. Thus, their WTP for haze mitigation might not be fully captured in this study.

Recommendations

Indonesia's forest fire problem is complex (Chisholm *et al* 2016). Even within the 43 million ha of forest lands set aside for conservation by a government moratorium in 2011, forest fires still occur. The ultimate drivers of the fires are global macroeconomic forces that incentivise land-use change. Palm oil production, in particular, is key to Indonesia's economic development and generated $19 billion in export revenue in 2014. The largest economic benefits of agriculture are straightforward to quantify and are concentrated among relatively few companies and individuals, while the costs of agriculture, including the fires, are diffuse and difficult to quantify, leading to a classic public goods problem (Chisholm *et al* 2016).

Our study, focussing on the costs of haze in Singapore, must be put in context of the broader costs of Southeast Asia's forests fires. Previous studies have incorporated a wider range of costs, including regional impacts on tourism, health, forestry, agriculture, global climate, biodiversity and other sectors and have employed a variety of direct and indirect valuation methods. The major 1997 event had estimated regional impacts of $4.5 billion (Glover and Jessup 1999). The 2015 fires cost Indonesia alone an estimated $16.1 billion (World Bank 2015).

Our estimate that Singaporeans are willing to pay $643.5 million per year for haze mitigation is complementary to the figures for regional impacts and the Singapore estimates from other methods cited earlier. Taking into account the estimates from other methods, which, as discussed earlier, largely measure a complementary set of impacts, the total impact on Singapore could easily be over $1 billion in a bad haze year, implying that the net present value of clean air is perhaps several billion dollars. Accordingly, Singapore should be willing to invest at least a few hundred million dollars to avert a bad haze year, or a few billion to permanently mitigate haze. Information on the WTP of residents of neighbouring countries, particularly Malaysia and Indonesia, would help complete this picture. A preliminary crude estimate of $1.8 billion for regional annual WTP can be obtained by scaling up our estimate for Singapore by the ratio of GDP of nearby haze-affected regions (GDP of Singapore, Malaysia, and Indonesian provinces in Sumatera, Kalimantan and nearby islands) to Singapore's GDP.

What policies could be implemented to mitigate the forest fires, given adequate financial resources and political will? Possibilities are investments in land conservation, peatland restoration, and sustainable peatland agriculture (Wijedasa *et al* 2017), perhaps in collaboration with concession-holding companies that have already demonstrated a willingness and ability to enforce conservation of high-value forests within their holdings. The Indonesian government estimates that 2.6 million ha burnt in 2015 fires, about 33% of which was on peatlands. The peatland fires generate much of the noxious haze that affects Singapore and other neighbouring areas. The World Bank has estimated that one-time peatland buybacks for the purposes of preventing fires would cost roughly $9.75 billion in Riau and $5.39 billion in Central Kalimantan—these two provinces together have 151 471 ha of peatland (World Bank 2016). The same report estimates that peatland restoration would cost on the order of $1 000 per hectare, which implies a required initial restoration investment of $452 million for priority peatland areas or $1.9 billion if the Indonesian government's stated goal of restoration of 2 million ha of peatlands by 2020 is to be achieved.

Conclusion

Singapore's WTP for haze mitigation, estimated here at $643.5 million per year, is sufficiently large that it could make a substantive impact on the problem, if realised and invested in land conservation and restoration. Our result should be used in conjunction

with those of other studies to produce holistic assessments of Indonesia's fires on the regional and global environment and to guide policymaking.

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