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Health Benefit Assessment of National Ambient Air Quality Standards for $PM_{2.5}$ in Taiwan

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Abstract

We used the Impact Pathway Approach to assess the health benefits from the National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ of Taiwan. The results indicated significant health benefits linked to the implementation of NAAQS for air basins in central and southern Taiwan. Meeting the "14+N Air Pollution Control Strategy" air quality targets reduced the mortality risk from $PM_{2.5}$ by 3,568 people on average. The health benefits from lower medical costs and cost of death was estimated at US$ 8.6 billion, or 1.5% of Taiwan's 2017 GDP. If NAAQS can be achieved through further efforts then mortality risk can be reduced by 6,664 people for estimated health benefits of US$16.1 billion, or 2.8% of Taiwan's 2017 GDP. The findings suggest that air quality standards provide an effective policy with significant health benefits. Combining the results of the cost-benefit assessment in this study with further cost-related data will facilitate a cost-performance analysis of air pollution management policies.

Keywords: $PM_{2.5}$, health benefits, National Ambient Air Quality Standards (NAAQS), impact pathway approach, cost-benefit analysis

1. Introduction

There is now domestic and international consensus on the health risks posed by air pollution. Human beings exposed to air pollution are at increased risk of heart disease, stroke, lung cancer, as well as acute and chronic respiratory illnesses that in turn increase their mortality risk and burden from higher medical expenditures (World Health Organization, 2018) .Research by the World Bank and U.S. Institute for Health Metrics and Evaluation (2016) indicated that around 5.5 million premature deaths worldwide in 2013 could be attributed to the effects of air pollution and accounted for 10% of global deaths for that year. Monetization of related losses put global health costs associated with air pollution at around US$5.1 trillion in 2013. If sorted by pollutant, the majority of these losses were due to effects of fine suspended particulates, or $PM_{2.5}$.

Air pollution prevention and control has always been a key aspect of environmental protection policy in Taiwan. To reduce the impact of air quality on public health, the "National Ambient Air Quality Standards" (NAAQS) were introduced by Taiwan in 2012. NAAQS required the annual average concentration of $PM_{2.5}$ in the atmosphere to be reduced to $15 \mu g/m^3$ by 2020 in line with the strictest international standards today. To meet this target, the Taiwan Environmental Protection Administration (Taiwan EPA) formally approved the "14+N Air Pollution Control Strategy"(14+N APCS) in 2017. A mix of incentives and controls would be used to implement 14 key control measures. A total of $215 billion in funding would be channeled towards the phased target of reducing the annual average concentrations of $PM_{2.5}$ to 18 $\mu g/m^3$ in 2019 (Taiwan EPA, 2017). The governance of air pollution risks involves not only the formulation of feasible prevention strategies on a technical level. Successful implementation of policies also depends on the use of cost-benefit analysis (CBA) from the economics sector to assess the distribution of costs and benefits during air pollution control. At the moment, a lack of CBA on reduction strategies at the national level means there is still a lack of related discussions (Risk Society and Policy Research Center of National Taiwan University, 2018)

In terms of the assessment itself, an estimation of health costs or benefits related to air pollution are two sides of the same coin that differ only in their standpoint. The subject of health cost assessments is the damage to public health from the emission of air pollutants. Health benefits focus on the improvements to cost of health from a reduction in polluting emissions. A reduction in cost therefore translates into benefits. In this context, mastering the method for measuring the health costs of air pollution means it can be applied to the assessment of health benefits as well.

The main method currently used internationally for a monetized assessment of health impacts from air pollution is known as the "Impact Path Approach"(IPA) (Shaw, *et al.*, 2002; Taiwan EPA, 2012a; 2012b). IPA is an assessment approach that combines different specialties and links together the outcomes from three phased simulations or assessments. When applied to the monetized assessment of health impacts from air pollution, the three phases are: (1) Simulating the effect of air pollution on changes in air pollution concentration, (2) estimating the variation in medical events due to changes in pollution concentration, (3) and monetized measurements corresponding to the variation in medical events. The advantage of IPA is its ability to clearly describe the impact pathways between emission of pollution to the affected subject at every phase. The impact of each phase can also be captured in a quantifiable manner.

There are currently two relatively mature types of international applications based on this approach. First of these was the "Externalities of Energy" (ExternE) that the European Commission (EC) began developing in the 1990s to assess the external cost of different energy technologies (EC, 2005). The other was the "Environmental Benefit Mapping and Analysis Program" (BenMAP) that the U.S. Environmental Protection Agency (U.S. EPA) began developing in 2003 and is used mainly for the monetization of health benefits from national-level air pollution prevention and control policies (U.S. EPA, 2018a). Regardless of whether it is the methodology favored in Europe or the U.S., their basic approaches are all based on IPA. Only the technical parameters used vary due to regional and national differences. Such an approach is often used for regulatory impact analysis (RIA) of air pollution policy proposals to gage the positive effects of policy implementation in terms of its health benefits. (Chae and Park, 2011; Berman *et al.*, 2012; Fann *et al.*, 2012; Fann *et al.*, 2009; Machol and Rizk, 2013; U.S. EPA, 2012; 2013; 2018b) 。

A review of literature in Taiwan showed an increase in the number of studies including science research projects on the health costs of air pollution caused by suspended particulates (including PM_{10} and $PM_{2.5}$) based around the IPA method and similar phased daisy-chaining approach since 2000. (Taiwan Power Company, 2004; Atomic Energy Council, Executive Yuan, 2007; Taiwan EPA, 2011a; 2012b; 2014) and journal articles (Liao, *et al.*, 2016). In most of these literatures the assessments focused on emission or reduction scenarios designed for a certain emission source. None simulated or assessed the health benefits of a control tool for air quality standards.

Based on the above research backdrop, the main purpose of this study is to use the IPA to assess the health benefits of the $PM_{2.5}$ air quality targets set out by the NAAQS and 14+NAPCS in Taiwan. The results of this study can be used to support CBA of subsequent management strategies in order to improve decision-making quality and efficiency.

2. Methodology: Application of the Impact Pathway Approach in this Study

2.1 Reduction in pollution concentration required to meet air quality standards

Phase 1 of IPA is to simulate the effect of emission reductions on pollution concentration in order to obtain the variation in concentration. When NAAQS is used as the policy scenario however there is already a target pollution concentration. The variation in concentration is based on the difference in pollution concentrations between the baseline year and the target year is as shown in Eq. (1).

$$\Delta C \quad = C_{policy} - C_{BAU} \tag{1}$$

In (1), C_{policy} is the $PM_{2.5}$ target pollution concentration in the policy scenario. C_{BAU}It represents the $PM_{2.5}$ target pollution concentration for the baseline scenario; ΔC represents the variation in concentration when the policy scenario is achieved.

2.2 Assessment of health impact

Phase 2 of IPA looks at the health impacts on receptors affected by the spread of pollution. The calculations must make use of the dose-response function.

Dose-response research in epidemiology generally make use of health risk indicators such as “relative risk (RR)” and “odds ratio (OR)”. Research literature that use RR usually use regression models with a Log-Linear function during analysis. Research that use OR mainly use the Logistic regression model as the analytical tool. The "health impacts function" derived from these two different tools will be different as well.

When a log-linear regression model is used the health impacts function is expressed as shown in Eq. (2): When a log-linear regression model is used the health impacts function is expressed as Eq. (3):

$$\Delta y = \left(1 - \mathrm{e}^{-\beta\Delta x}\right) \times y_0 \tag{2}$$

$$\Delta y = \left\{1 - \left[(1 - \mathrm{y}_0) \times \mathrm{e}^{\beta\Delta x} + \mathrm{y}_0\right]^{-1}\right\} \times y_0 \tag{3}$$

In the two above equations, y_0 is the background incidence rate of certain illnesses in different medical events while Δy represents the change in this incidence rate;Δx is the variation in pollution concentration while β is the coefficient of estimation obtained through empirical analysis of the dose-response function.

When a change in pollution concentrate leads to a change in the incidence of specific medical events, its product with the potential number of people affected gives the "medical event incidence rate" (I) brought about by the change in pollution as defined in Eq. (4).

$$I = \Delta y \times pop \tag{4}$$

Here pop represents the population affected by this event.

2.3 Monetization of health impacts

The final phase of IPA is to monetize the health impact and use it to calculate the cost or benefit. The health impacts that this study ultimately decided to take into account based on the types of dose-response functions available were the variations in "mortality risk" and "morbidity risk." Their corresponding monetization were "value of statistical life" (VSL) and "cost of illness" (COI) respectively.

The price that an individual was willing pay (accept) for a minute reduction (increase) in mortality risk was used as the basis for inferring VSL. In other words, VSL was estimated using individuals' evaluations of changes in mortality risk. From this we can then define VSL as each person's willingness-to-pay (WTP) for a variation that lowers their mortality risk as represented by Eq. (5).

$$\mathrm{VSL}_i = WTP_i(\Delta risk)/\Delta risk \tag{5}$$

In the above equation, $\Delta risk$ represents a minute change in mortality risk.

At the same time, COI uses changes in actual medical expenditure to infer the benefits or costs associated with a change in the morbidity risk for certain illnesses. Calculation involves classification of the medical events (including outpatient clinic, admission, emergency) for different diseases and the statistics on their corresponding actual medial expenditures. In addition, COI must usually take lost productivity due to illness into account in order provide the most complete picture of opportunity cost possible.

The above standard three-phase IPA assessment process can be used to simulate the health benefits of achieving the air quality standards. The IPA assessment process applied in this study can be summarized as shown in **Fig. 1**.

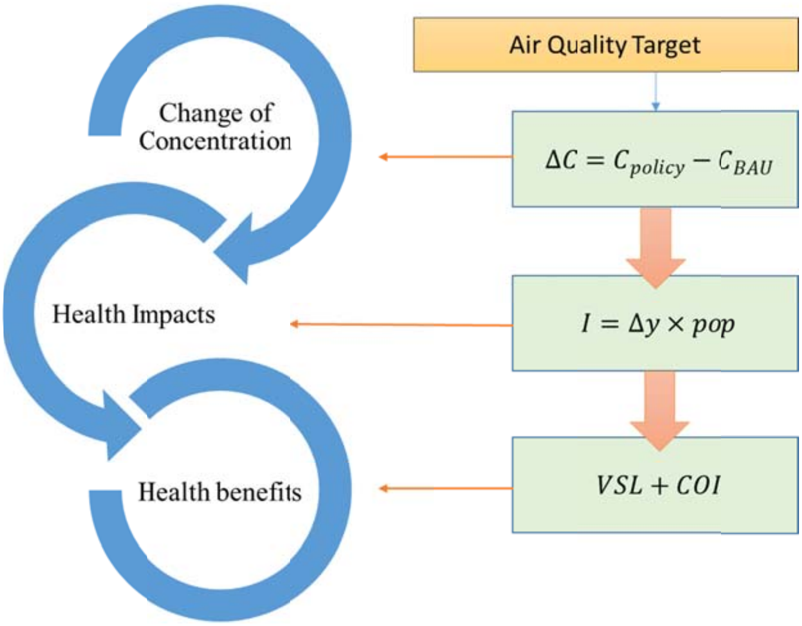

Figure 1: The simulation process for health benefits used in this study

3. Source of empirical data and their treatment:

3.1 Reduction in pollution concentration required to meet air quality standards

Seven air basins based on administrative divisions were designated by Taiwan for management and monitoring purposes. The counties and cities encompassed by each air basin are as shown below.

- Air Basin 1: Taipei City, New Taipei City, Keelung City, Taoyuan City;
- Air Basin 2: Hsinchu County, Hsinchu City, Miaoli County;
- Air Basin 3: Taichung City, Changhua County, Nantou County;
- Air Basin 4: Yunlin County, Chiayi County, Chiayi City, Tainan City;
- Air Basin 5: Kaohsiung City, Pingtung County
- Air Basin 6: Yilan County;
- Air Basin 7: Hualien County, Taitung County

The average annual concentration of $PM_{2.5}$ for Taiwan in 2017 was designated by this study as Business as Usual (BAU). The concentration data of the seven air basins were sourced from the *2017 Green GDP* report published by the Directorate General of Budget, Accounting and Statistics (DGBAS) (2018a). The policy scenarios included:

- Policy Scenario 1: 14+N APCS $PM_{2.5}$ concentration target 18μg/m^3;

- Policy Scenario 2: NAAQS $PM_{2.5}$ concentration target 15μg$/m^3$.

The difference between the BAU and target concentrations of each air basin under different scenarios was graphed and shown in **Fig.2**. For a target concentration of 18μg$/m^3$ under Policy Scenario 1, pollution reduction was only necessary in Air Basins 3, 4, and 5. The magnitudes of reductions were 2.3μg$/m^3$, 6.8μg$/m^3$, and 3μg$/m^3$ respectively. For a target concentration of 15μg$/m^3$ under Policy Scenario 2, Air Basins 1, 2, 3, 4 and 5 must all engage in pollution reduction. The magnitudes of reductions are 0.2μg$/m^3$, 1.9μg$/m^3$, 5.3μg$/m^3$, 9.8μg$/m^3$ and 6μg$/m^3$ respectively. Air Basins 6 and 7 met the concentration targets for both policy scenarios so did not need to engage in air quality improvements.

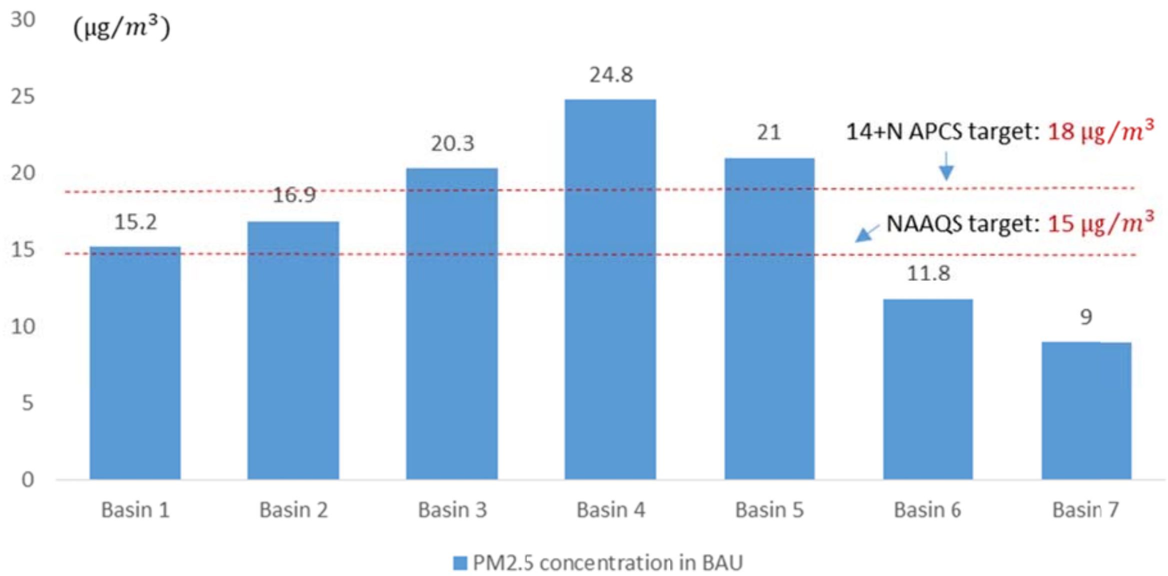

Figure 2: The BAU and target concentrations under different policy scenarios in Taiwan on 2017

3.2 Assessment of health impact

A RIA was conducted by U.S. EPA (2012) for legislation to control $PM_{2.5}$. Listed in the report were the coefficients in dose-response functions for quantifying the health effects of $PM_{2.5}$ and these provide a basis for the calculation of the health impact. The two types of health risks assessed in the report were "mortality" and "morbidity"; Health events encompassed "admission", "outpatient clinic" and "emergency." The Taiwan EPA (2014) referred to the health impact assessment items in the U.S. EPA (2012) and substituted the coefficients of their dose-response functions where local Taiwanese research was available for assessments in Taiwan.

The above setup meant that a total of 14 dose-response function coefficients were needed to calculate health impact. Seven of the items used localized Taiwanese dose-response function coefficients for the health impact calculation. These were " diseases of the circulatiry system ", "acute myocardial infarction ", " other ischaemic heart disease ", " cerebrovascular disease ", "pneumonia", and " bronchitis, chronic and unspecified, emphysema and asthma" in "admission" medical events, and "asthma" in "emergency" medical events. These coefficients of the dose-response functions cited in this study are summarized in **Table 1**.

The background incidence rate (y_0) of specified medical events were obtained from the statistical data in the Ministry of Health and Welfare's (2017) *Statistical Annual Report: The National Health Insurance Statistics, 2015*. The "treatment rate per 100,000 people" was used as the measurement indicator. This study assumed a homogeneous effect from pollution concentrations on the entire population of the same county/city. To calculate the population affected by the health impact (pop), the number of people in a certain age group within that county/city (based on the age-group of those in the dose-response study that the health effects correspond to) was used as the measurement indicator. These data came from the Department of Household Registration, Ministry of the Interior (2018) *Population Statistics Database*. Finally, Eq. (4) is used to determine the variation in medical events (I) under each scenario.

3.3 Monetizing the effect of health impacts

The "benefit transfer method" was used in this study with the latest available VSL research findings in Taiwan to transfer the monetized value brought about through the reduction of mortality risk in this study. The VSL value calculated by Liu (2011) was used as the basis then deflated using the wage/consumer price index to give VSL = US$ 3.42 million/person based on 2017 price levels. The value was then used to infer the benefits from a reduction in mortality risk for this study.

To calculate COI, this study used data from the *2015 National Health Insurance Medical Statistics Annual Report* published by the Ministry of Health and Welfare (2017). The average medical costs of each person for each disease listed in **Table 2** was then calculated. In addition, the average wage of employed workers for that year was also used as an indicator to measure the opportunity costs on income lost due to debilitating illnesses. The average wage data was from DGBAS (2018b). This cost calculation varies for each category of medical events. In the "admission" category, lost work is based on treating the number of days hospitalized due to that illness as the number of lost work days; or "emergency" and "outpatient clinic", the number of lost work days due to the specified illness was assumed to be one day. Based on the above, the average medical costs for each disease was found to be as shown in **Table 2**.

Table 1: Dose-response research and $\boldsymbol{\beta}$ coefficients adopted by this study

<table>
<tr><td colspan="2">Diseases & medical events</td><td>ICD 9 CM</td><td>Age</td><td>References</td><td>Functional form</td><td>$\boldsymbol{\beta}$</td></tr>
<tr><td colspan="2" rowspan="2">Mortality</td><td>All</td><td>30-99</td><td>Krewski et al. (2009)</td><td>Log-Linear</td><td>0.005827</td></tr>
<tr><td>All</td><td>25-99</td><td>Lepeule et al. (2012)</td><td>Log-Linear</td><td>0.013103</td></tr>
<tr><td rowspan="8">Admission</td><td>Diseases of the circulatiry system</td><td>390-459</td><td>0-99</td><td>Taiwan EPA (2011b)</td><td>Logistic</td><td>0.0061</td></tr>
<tr><td>Acute myocardial infarction</td><td>410</td><td>0-99</td><td>Chang et al. (2013)</td><td>Logistic</td><td>0.0055</td></tr>
<tr><td>Other ischaemic heart disease</td><td>411-414</td><td>0-99</td><td>Taiwan EPA (2011b)</td><td>Logistic</td><td>0.0088</td></tr>
<tr><td>Cerebrovascular disease</td><td>430-438</td><td>0-99</td><td>Taiwan EPA (2011b)</td><td>Logistic</td><td>0.0079</td></tr>
<tr><td>Chronic diseases of lung</td><td>460-519</td><td>65-99</td><td>Zanobetti et al. (2009)</td><td>Log-Linear</td><td>0.0021</td></tr>
<tr><td>Pneumonia</td><td>480-486</td><td>0-99</td><td>Tsai et al. (2014)</td><td>Logistic</td><td>0.0065</td></tr>
<tr><td>Bronchitis, chronic and unspecified, emphysema and asthma</td><td>490, 492, 494, 496</td><td>0-99</td><td>Tsai et al. (2013)</td><td>Logistic</td><td>0.0065</td></tr>
<tr><td rowspan="2">Emergency</td><td rowspan="2">Asthma</td><td rowspan="2">493</td><td>5-14</td><td>Chen et al. (2013)</td><td>Logistic</td><td>0.01431</td></tr>
<tr><td>20-64</td><td>Glad et al. (2012)</td><td>Logistic</td><td>0.0052</td></tr>
<tr><td rowspan="3">Outpatient clinic</td><td>Acute bronchitis and bronchiolitis</td><td>466</td><td>5-14</td><td>Dockery (1996)</td><td>Logistic</td><td>0.027212</td></tr>
<tr><td>Other acute upper respiratory infections, Diseases of upper respiratory tract</td><td>460-465, 470-478</td><td>5-14</td><td>Pope (1991)</td><td>Logistic</td><td>0.0036</td></tr>
<tr><td>Lower respiratory infections</td><td>480-487</td><td>5-14</td><td>Schwartz (2000)</td><td>Logistic</td><td>0.019012</td></tr>
</table>

Table 2: Medical expenditure, lost work and cost of illness

Diseases & medical events		cost of illness (US$/person)
Admission	Diseases of the circulatiry system	2,202
	Acute myocardial infarction	1,145
	Other ischaemic heart disease	1,679
	Cerebrovascular disease	1,748
	Chronic diseases of lung	3,886
	Pneumonia	1,423
	Bronchitis, chronic and unspecified, emphysema and asthma	1,963
Emergency	Asthma	110
		152
Outpatient clinic	Acute bronchitis and bronchiolitis	118
	Other acute upper respiratory infections, Diseases of upper respiratory tract	99
	Lower respiratory infections	89
Note 1: deduct 410, 411-414, 430-438 to avoid repeated calculations.		

4. Simulation result

4.1 Prevention of mortality risk and reduction in medical events

The variation in health impacts for each Air Basin under different policy scenarios are summarized in **Table 3** and **Table 4**. Simulations found that improvements in air quality significantly reduced mortalities linked to air pollution in each air basin. Under Policy Scenario 1, mortality was reduced by an average of 3,568 people; under Policy Scenario 2, mortality was reduced by an average of 6,664 people. The spatial distribution of mortalities avoided by improvements in air pollution is as shown in **Fig. 3**. The relatively poor BAU air quality in Air Basins 3, 4 and 5 meant that the mortality risk avoided during the process of improving air quality to meet targets was correspondingly higher as well.

4.2 Health benefits

This study adopted the approach used by U.S. EPA (2012; 2013; 2018) in basing calculations for the change in mortality on two different studies of dose-response functions for mortality risk. The mortality risk cost calculated with the higher dose-response coefficient (Lepeule et al., 2012) was set as the upper limit of the measured health benefits, while the mortality risk cost calculated with the risk coefficient (Krewski et al., 2009) was set as the lower limit of the measured health benefits. The results of the simulation are as shown in **Table 5**. The spatial distribution of health benefits in different air basins is as shown in **Fig. 4**.

The estimated outcomes in Table 5 show that very significant health benefits can be achieved when air quality targets are used as the control tool. Under Policy Scenario 1, the health benefits of meeting the 14+N APCS air quality standards were estimated to be between US$ 4.99 billion to US$ 12.3 billion. Average value was US$ 8.62 billion or approximately 1.5% of Taiwan's 2017 GDP. Under Policy Scenario 2, the health benefits of meeting the NAAQS air quality standards were estimated to be between US$ 9.38 billion to US$ 22.9 billion. Average value was US$ 16.1 billion or approximately 2.8% of Taiwan's GDP in 2017.

Table 3: Reduction in medical events under Policy Scenario 1 (number of persons)

Diseases & medical events		Basin 3	Basin 4	Basin 5
Mortality		346	741	355
		1,377	2,905	1,411
Admission	Diseases of the circulatiry system	324	694	333
	Acute myocardial infarction	309	662	317
	Other ischaemic heart disease	249	531	256
	Cerebrovascular disease	5,567	11,908	5,716
	Chronic diseases of lung	17	45	20
	Pneumonia	25	54	26
	Bronchitis, chronic and unspecified, emphysema and asthma	329	705	338
Emergency	Asthma	16	31	15
		8,611	18,550	8,986
Outpatient clinic	Acute bronchitis and bronchiolitis	4,574	9,167	4,132
	Other acute upper respiratory infections, Diseases of upper respiratory tract	773	1,495	695
	Lower respiratory infections	2,064	3,875	1,845
Note: under the policy scenario 1, the Basin 1, Basin 2, Basin 6, and Basin 7 have reached the target, so they are not included.				

Table 4: Reduction in medical events under Policy Scenario 2 (number of persons)

Diseases & medical events		Basin 1	Basin 2	Basin 3	Basin 4	Basin 5
Mortality		61	97	789	1,059	704
		245	386	3,112	4,107	2,768
Admission	Diseases of the circulatiry system	57	91	739	991	659
	Acute myocardial infarction	54	86	705	946	629
	Other ischaemic heart disease	44	70	567	755	505
	Cerebrovascular disease	984	1,559	12,698	16,989	11,318
	Chronic diseases of lung	3	5	40	65	40
	Pneumonia	4	7	57	77	51
	Bronchitis, chronic and unspecified, emphysema and asthma	58	92	752	1,007	670
Emergency	Asthma	3	5	37	44	29
		1,530	2,349	19,805	26,681	17,937
Outpatient clinic	Acute bronchitis and bronchiolitis	748	1,447	10,779	13,497	8,451
	Other acute upper respiratory infections, Diseases of upper respiratory tract	129	245	1,779	2,150	1,387
	Lower respiratory infections	348	657	4,655	5,466	3,613
Note: under the policy scenario 2, the Basin 6, and Basin 7 have reached the target, so they are not included.						

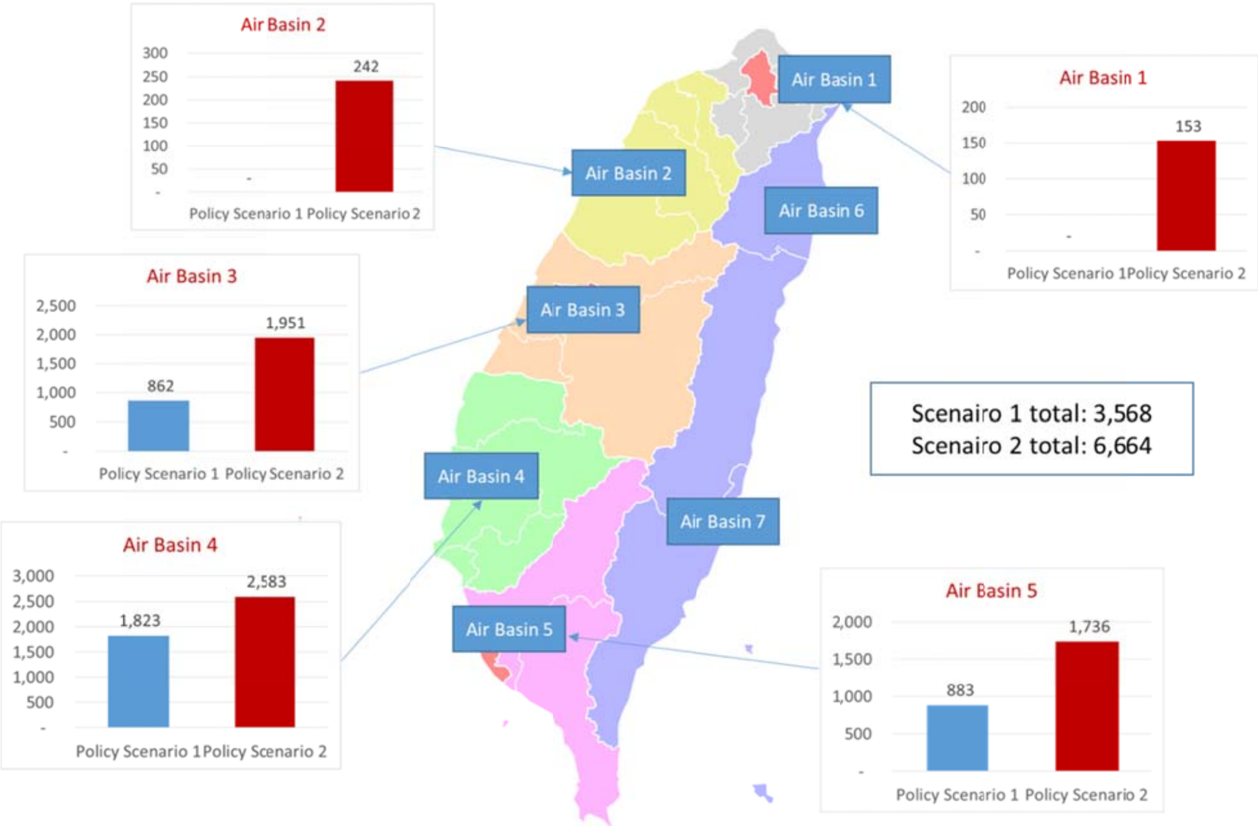

Figure 3: Reduction in mortality due to improvements in air pollution under different policy scenarios (number of persons)

Table 5: Simulation results for health benefits in each air basin (US$ billion)

Basin	Upper limit	Lower limit	Average
Policy scenario 1			
Basin 3	29.60	11.96	20.78
Basin 4	62.64	25.63	44.13
Basin 5	30.34	12.28	21.31
Total	122.58	49.87	86.22
Policy scenario 2			
Basin 1	5.26	2.11	3.69
Basin 2	8.30	3.35	5.82
Basin 3	67.04	27.31	47.17
Basin 4	88.74	36.62	62.68
Basin 5	59.65	24.35	42.00
Total	228.99	93.74	161.36

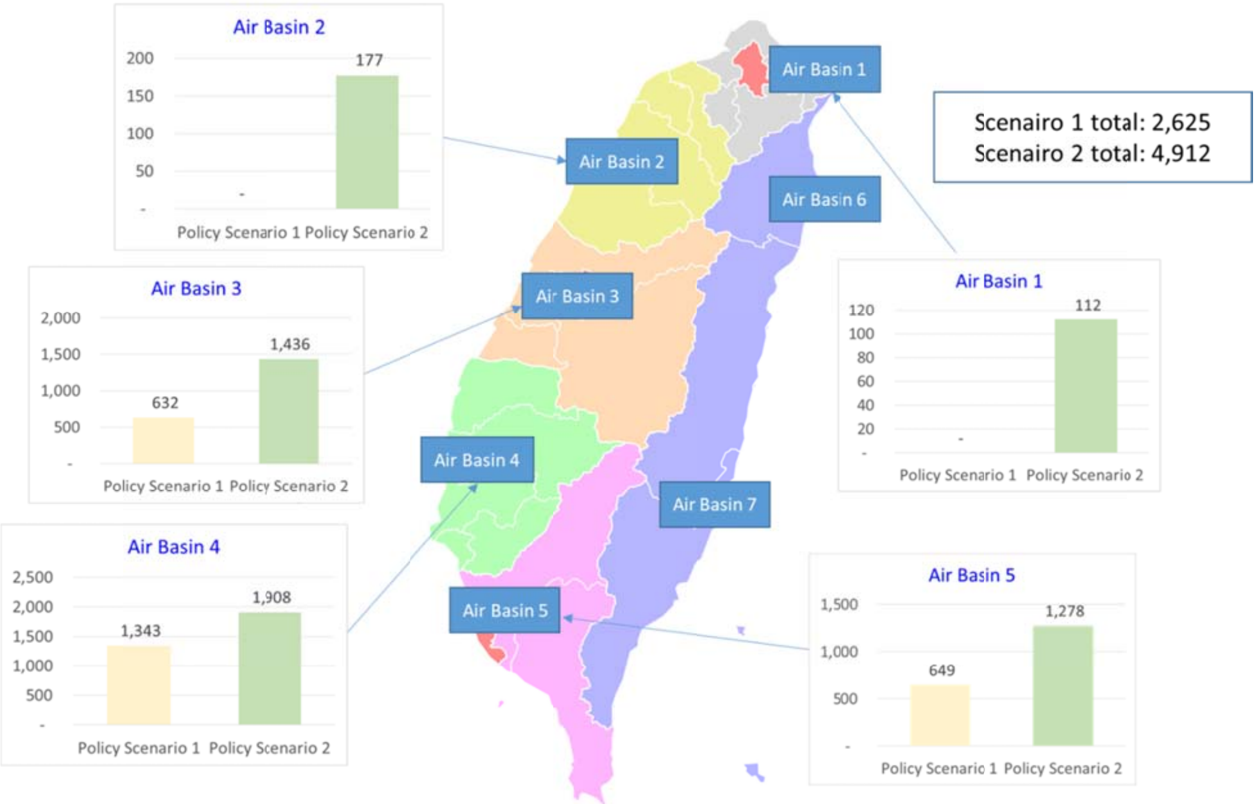

Figure 4: Health benefits from improvements to air pollution under different policy scenarios (US$ billion)

5. Conclusion and Recommendations for Further Follow-up

IPA was applied in this study to simulate and assess the health benefits of the $PM_{2.5}$ concentration targets set by 14+N APCS and NAAQS. An assessment of the simulation results indicated that the "14+N Air Pollution Control Strategy" can be expected to bring between US$ 4.99 billion to US$ 12.3 billion in health benefits, with the average being US$ 8.62 billion. The health benefits corresponding to NAAQS ranged between US$ 9.38 billion to US$ 22.9 billion, with the average being US$ 16.1 billion. The health benefit simulation results obtained by this study can be applied to air pollution prevention strategies to effectively determine the benefits of improvements in pollution. Cost data can also be introduced to improve the quality of prevention strategies, and support their implementation through cost-benefit analysis on a strategic level and the establishment of related narratives.

Several limitations also exist in this study. First, the IPA simulation results in this study used mainly the annual concentration of air quality as the simulation time scale so can only be used as a representation of average conditions for the year. One of the limitations is therefore its inability to describe changes in benefits over a finer time scale. Second, there is still room for improvement in some of the technical parameters and this should be considered a direction for further refinement in the future. For example, though international parameters were substituted by localized research findings on dose-response functions, a relatively high proportion of the parameters have not been localized yet. Once further literature becomes available more localized research findings on dose-response functions can be introduced so that the measurement of health risks can better reflect conditions in Taiwan. In addition, while the medical costs in the monetization stage can be updated using annual statistics published by the Ministry of Health and Welfare, what is even more important is the updating of VSL data (due to the higher weighting of benefits from reduction in mortality risk during the estimation of health benefits). The VSL assessment results cited here reflect 2006 conditions so the data is quite old already. If more recent empirical data can be used to update the results of the VSL assessment then the simulation results for health benefits can be made more persuasive.

In terms of applied research, a review of recent literature involving monetization and analysis of the air pollution health effects found research topics that were had links to the general economic model - "computable general equilibrium"(CGE) for example explored how changes in air quality can influence the overall economy through the labor market. In addition, assessing the co-benefits of air pollution reduction from the implementation of different response measures for mitigation under the framework of global climate change governance offers another research direction where IPA can be applied.

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