Economic evaluation of environmental epidemiological projects in national industrial complexes

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In this economic evaluation of environmental epidemiological monitoring projects, we analyzed the economic feasibility of these projects by determining the social cost and benefit of these projects and conducting a cost/benefit analysis. Here, the social cost was evaluated by converting annual budgets for these research and survey projects into present values. Meanwhile, the societal benefit of these projects was evaluated by using the contingent valuation method to estimate the willingness-to-pay of residents living in or near industrial complexes. In addition, the extent to which these projects reduced negative health effects (i.e., excess disease and premature death) was evaluated through expert surveys, and the analysis was conducted to reflect the unit of economic value, based on the cost of illness and benefit transfer method. The results were then used to calculate the benefit of these projects in terms of the decrease in negative health effects. For residents living near industrial complexes, the benefit/cost ratio was 1.44 in the analysis based on resident surveys and 5.17 in the analysis based on expert surveys. Thus, whichever method was used for the economic analysis, the economic feasibility of these projects was confirmed.

Keywords: Environmental epidemiological projects, Economic evaluation, Cost/benefit analysis, Benefit/cost ratio, Health effects, Willingness-to-pay

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INTRODUCTION

The economic evaluation of these environmental epidemiological monitoring projects is the task of analyzing the social cost and benefit of these projects and evaluating their economic feasibility. The social cost of environmental epidemiological monitoring projects can be easily determined from the budget invested in such projects. On the contrary, the effects of these projects are showed up as goods and services that exist outside of markets, such as reduced resident anxiety and decreased negative health effects due to improved environmental quality. Thus, in the present study, the benefit of these projects is estimated by using a valuation method for non-marketed goods.

To evaluate the benefit, two methods are used: (1) residents near industrial complexes are surveyed to ascertain their willingness-to-pay (WTP) for these projects, and (2) the benefit due to reduced negative health effects is analyzed through a survey of experts in relevant fields. These two methods can be considered to be separate approaches to quantifying the benefit of these projects by using existing available data.

METHODS

To study the economic effect of environmental epidemiological monitoring projects, an economic analysis (i.e., cost/benefit analysis) was conducted, enabling the economic feasibility of these projects to be assessed based on their cost and benefit.

The cost of these projects can mostly be considered to be the budget invested in these projects, but it could also include increased in-house investment in facility upgrades and operating costs by companies in national industrial complexes if they are influenced by these projects. Meanwhile, the major benefit of

these projects includes the decrease in the health effects (disease and premature death) of industrial complexes as well as the decrease in anxiety for people affected by industrial complexes, including local residents. There is also the beneficial effect of improved environmental quality, which in turn has benefits for the health of local residents and reduces the negative effects on local ecosystems.

First, the analysis of the social cost of these projects was based on the budget invested in these projects, by referring to budget accounts data. Subsequently, based on the disease prevention benefits of these projects, the inclusion of other social benefits was reviewed. Methodologies that evaluate the economic value of disease prevention or other non-marketed goods include the cost of illness, the averting behavior method, the contingent valuation method, the choice experiment method, and the benefit transfer method [1].

This study used the contingent valuation method to determine the WTP for these projects of residents living near or within industrial complexes. In so doing, we attempted to quantify, in monetary terms, the benefit of these projects as perceived by local residents. Here, all the perceivable benefits of these projects could be considered to be included, such as improved environmental quality, reduced disease, and reduced anxiety.

In addition, an expert panel was surveyed to ascertain the health effects of industrial complexes and the reduction in these health effects due to projects; the benefit of these projects in terms of reduction in disease and premature death was then converted into a monetary value. Here, the cost of illness and the benefit transfer were used in these analyses.

Finally, in the economic analysis (i.e., cost/benefit analysis), the quantified cost and benefit of these projects was used to evaluate their economic feasibility, based on the benefit/cost (B/C) ratio and net present value. A sensitivity analysis was then conducted to examine the effects on project feasibility if there was any change in cost or benefit.

RESULTS

Cost Evaluation

Looking at the budgets within the survey area for national industrial complexes in stage 1 (2003–2010) and stage 2 (2012–2015) of the survey, the total budget in stage 1, from 2006 to 2010, was 5.530 billion Korean won (KRW), while the total budget in stage 2, from 2012 to 2015, was 5.751 billion KRW.

To convert all costs into present values in 2015 for the cost/benefit analysis, the consumer price index was used to recalculate these research costs. The present value budgets were 6.420 billion KRW for stage 1 and 5.841 billion KRW for stage 2,

meaning that the total budget was 12.261 billion KRW.

Benefit Evaluation

Estimated Benefit for Residents Living Near Industrial Complexes

To derive the benefit of neighborhood environmental epidemiological projects in national industrial complexes from the WTP of local residents, the contingent valuation method was used, which is a type of stated preference method for valuing non-marketed goods. The subjects of the questionnaire were households in regions exposed to national industrial complexes and the total number of households in the regions of Sihwa/Banwol, Cheongju/Daesan, Pohang, Ulsan, and Gwangyang/Yeosu was 328 444 [2]. Residents living near or within industrial complexes responded to dichotomous choice questions about these projects, and these responses were used to estimate a WTP model. From this, we estimated the annual WTP of households towards these projects.

When the WTP estimate was used to calculate the annual WTP per household, the WTP of households that had previously participated in environmental epidemiological surveys for national industrial complexes was 6660 KRW per year (95% confidence interval [CI], 4612 to 9618 KRW). Meanwhile, the WTP of households that had never participated in environmental epidemiological surveys for national industrial complexes was 5975 KRW (95% CI, 4596 to 7768 KRW) (Table 1).

Multiplying the WTP per participating household by 1402, which was the number of participating households, gave a total WTP of 9 million KRW (95% CI, 6 to 13 million KRW). Meanwhile, when the population is restricted to those households liv-

Table 1. Annual willingness-to-pay (WTP) for environmental epidemiological projects in national industrial complexes, by household (including non-payers)

Type	WTP
Households with previous participation	6660 (4612, 9618)
Households without previous participation	5975 (4596, 7768)

Values are presented as mean (95% confidence interval).
Unit: Korean won.

Table 2. Annual willingness-to-pay (benefit) for environmental epidemiological projects in national industrial complexes, by residents living near industrial complexes

Type	Population (households)	Annual benefit	95% CI	
			Lower bound	Upper bound
Survey participant	1402	9	6	13
Local resident	327 042	1954	1503	2540
Total	328 444	1963	1510	2554

Unit: million Koran won.
CI, confidence interval.

ing near an industrial complex that have not previously participated in surveys, the WTP was 1.954 billion KRW (95% CI, 1.503 to 2.540 billion KRW). Thus, the total benefit of these projects for households near industrial complexes was 1.963. billion KRW per year, with a 95% CI of 1.510 to 2.554 billion KRW (Table 2).

Estimated Benefit Due to Health Effects Based on the Survey of Experts

A questionnaire was distributed to 27 experts in the field of environmental health or who had participated in these projects to determine the extent of health effects due to national industrial complexes as well as the reduction in these health effects (disease and premature death) achieved by these projects. The experts reported that local environmental pollution caused by national industrial complexes affected residents' health and that environmental epidemiological projects in national industrial complexes reduced environmental pollution. Thus, they believed that these projects decreased negative health effects, leading to a reduction in disease and mortality. The social benefit of the health impact due to these projects was estimated based on the evidence presented by these experts.

Estimated Benefit From a Reduction in Disease

Regarding the effects of environmental epidemiological monitoring projects in national industrial complexes, when the population is defined as those residing near industrial complexes (exposed regions), the size of the population near Sihwa/Banwol, Cheongju/Daesan, Pohang, Ulsan, and Gwangyang/Yeosu was 824 074 people [2]. According to the 2015 Population and Housing Census [3], the total national population is 51 069 375 people, meaning that the population near national industrial complexes represents 1.61% of the total population.

The total national annual treatment cost per disease category [4] was multiplied by this percentage (1.61%) to estimate the treatment cost per disease for the target population living near national industrial complexes. When residents living near industrial complexes are included in the industrial complex region, the annual treatment costs for skin disease, respiratory disease, and cardiovascular disease in industrial complex regions were estimated to be 240.311 billion KRW (Table 3).

Based on the expert survey, the mean excess percentage of disease caused by national industrial complexes was 11.3% for skin disease, 15.5% for respiratory disease, and 8.7% for cardiovascular disease. Meanwhile, among the excess health effects caused by industrial complexes, the mean percentage reduction reported due to these projects was 1.4% (range, 0.7 to 2.1%) for skin disease, 4.7% (range, 2.8 to 6.6%) for respiratory disease, and 4.1% (range, 3.2 to 5.0%) for cardiovascular disease (Table 4).

Estimated Benefit From a Reduction in Premature Death

Looking at mortality trends in Korea in the past five years, annual mortality is increasing slightly, and stood at 541.5 deaths per 100 000 population in 2015. This figure was used as the standard in this analysis. By applying the standard mortality rate to the percentage of the population included in the definition of industrial complex regions, the annual number of deaths in industrial complex regions was estimated. The percentage of excess deaths caused by industrial complexes, reported as 8.0% by the expert panel, was then applied to this estimate to calculate the number of excess deaths per year due to industrial complexes.

Meanwhile, the mean reduction in these excess deaths achieved by these projects was reported to be 2.3% by the panel of experts, with a range of 1.6 to 3.1%. This reduction was applied to the excess deaths caused by industrial complexes to calculate the

Table 3. Estimated annual treatment costs in industrial complex regions

Disease category	Nationwide annual treatment cost	Annual treatment costs for residents living near industrial complexes
Skin disease (diseases of the skin and subcutaneous tissue)	1 257 380	20 290
Respiratory disease (diseases of the respiratory system)	6 019 678	97 136
Cardiovascular disease (diseases of the cardiovascular system)	7 615 457	122 886
Total	14 892 515	240 311

Unit: million Korean won.

Table 4. Reduction in health effects (disease) caused by industrial complexes as a benefit of environmental epidemiological projects, according to a panel of experts

Disease category	Excess disease incidence cause by industrial complexes (%)	Reduction in excess disease due to these projects (%)		
		Mean	Minimum	Maximum
Skin disease	11.3	1.4	0.7	2.1
Respiratory disease	15.5	4.7	2.8	6.6
Cardiovascular disease	8.7	4.1	3.2	5.0

Table 5. Reduction in annual excess deaths achieved by environmental epidemiological projects, according to a panel of experts

Category	Mean	Minimum	Maximum
Reduction in excess mortality (%)	2.3	1.6	3.1
Reduction in deaths (people/y)	8.4	5.6	11.1

Table 6. Benefit transfer based on the VSL (as of 2015 KRW) derived from a previous domestic study[1]

Category	VSL (95% confidence interval)
Study	700 (590, 892)

Unit: million KRW.
VSL, value of statistical life; KRW, Korean won.
[1]From Shin Y, et al. Environ Resour Econ Rev 2003;12(1):49-74 (Korean) [5].

number of deaths prevented by these projects. When industrial complex regions were limited to residents living near industrial complexes, the number of deaths prevented by neighborhood projects was 8.4 deaths per year (Table 5).

The value of statistical life estimates presented by Shin and Joh [5] were considered to be appropriate for measuring the benefit of premature death prevention by environmental policies, and so these estimates were used in this analysis after converting into present values in 2015 (Table 6).

Total Benefit From Reduction in Health Effects

When industrial complex regions were limited to the region surrounding the industrial complex, based on the expert survey, the mean benefit of these projects from a reduction in disease was 1.174 billion KRW per year, of which 33 million KRW was for skin disease, 707 million KRW was for respiratory disease, and 434 million KRW was for cardiovascular disease. The range of benefit from a reduction in disease was 0.780 to 1.568 billion KRW per year.

Meanwhile, the benefit of these projects due to a reduction in premature death was 5.866 billion KRW per year, with a range of 3.950 to 7.781 billion KRW. Therefore, for restricted regions surrounding industrial complexes, the benefit of these projects due to a reduction in disease and premature death was, on average, 7.039 billion KRW per year (range, 4.730 to 9.348 billion KRW) (Table 7).

Economic Evaluation

The B/C ratio is a method of selecting the plan with the largest benefit relative to cost in terms of present values. Because the cost and benefit of projects are incurred over a long period of time, a discount is applied and the values are converted into a particular time period (generally the present year) to provide so-called present values. For individual projects, after conversion into present values, the project is generally considered to be

Table 7. Benefit of reduced excess deaths due to environmental epidemiological projects: residents living near industrial complexes

Health effect	Category	Mean	Minimum	Maximum
Disease	Skin	33	16	49
	Respiratory	707	424	991
	Cardiovascular	434	340	527
	Subtotal	1174	780	1568
Deaths	Excess deaths	5866	3950	7781
Total		7039	4730	9348

Unit: million Korean won.

Table 8. Economic analysis results of environmental epidemiological monitoring projects for national industrial complexes, residents living near industrial complexes

Category	Benefit (B)	Cost (C)	Net benefit	B/C
Local resident survey	17 671	12 261	5410	1.44
Expert survey	63 353	12 261	51 092	5.17

Unit: million Korean won.

economically feasible if the B/C ratio is ≥ 1.00.

When the population in industrial complex regions is restricted to people living near industrial complexes, these regions contain 824 074 people in 328 444 households. In this economic analysis of these projects, where only regions near industrial complexes were included in the study population, we estimated the benefit based on a survey of residents in industrial complex regions as well as the benefit from health effects based on an expert panel.

In the economic analysis of environmental epidemiological monitoring projects in national industrial complexes based on a survey of local residents, the B/C ratio was 1.44 and the net benefit was 5.410 billion KRW. Since the social benefit is greater than the social cost, this demonstrates the economic feasibility of these projects.

Meanwhile, in the economic analysis based on the expert panel survey, the B/C ratio was 5.17 and the net benefit was 51.092 billion KRW. Thus, calculating the benefit of these projects based on the results of an expert panel showed a 3.6-fold greater social benefit than calculations based on a survey of residents living in industrial complex regions (Table 8).

CONCULSION

If the industrial complex population is defined based on the administrative regions (city, si) containing industrial complexes, the population consists of 4 261 310 people in 1 613 178 households. When an economic analysis of these projects is conducted based on these conditions, the benefit of these projects increases 5-fold compared with the analysis using the population living near industrial complexes.

An economic analysis of the benefit of environmental epidemiological monitoring projects for residents in regions with national industrial complexes shows a B/C ratio of 7.08 and a net benefit of 74.498 billion KRW. Meanwhile, in an economic analysis based on an expert panel, the B/C ratio increases to 26.78 and the net benefit increases to 316.110 billion KRW. Therefore, when the scope of the industrial complex region affected by these projects is expanded from the surrounding area to the administrative region containing the industrial complex, the economic feasibility of these projects is very high.

Nevertheless, our method of benefit analysis using a survey of residents only evaluated those aspects perceived by residents, while the benefit analysis based on an expert panel only considered the direct medical costs. In this respect, our study could have underestimated the benefit of these projects.

ACKNOWLEDGEMENTS

CONFLICT OF INTEREST

The author has no conflicts of interest associated with the material presented in this paper.

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