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Measuring the economic benefits of an environmental monitoring satellite project: The value of information approach

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ABSTRACT

This paper reports a first application of contingent valuation method to measure the value of information generated by earth science data from an environmental geostationary satellite payload called Geostationary Environmental Monitoring Satellite. The purpose of the space project is to improve the accuracy of air pollution information by enhancing air pollution monitoring and forecasting system coupled with conventional ground level monitoring stations located throughout South Korea.

Estimation results based on a survey data of 1000 households show that most explanatory variables including bid amounts and household income significantly influenced dichotomous choice contingent valuation responses with expected signs. When applied to the whole sample, mean willingness to pay reflecting both use and non-use values was stable at around $3.70 per year for the improvement of air quality information. Present values of total benefits over the lifetime period of the space satellite exceed the cost born by tax payers with a benefit-cost ratio of 2.77. The result of this study clearly suggests that contingent valuation method can be used as an alternative approach in measuring the value of information from a space-derived earth science project.

1. Introduction

In recent decades, the South Korean government has made steady progress toward achieving cleaner air quality by better managing and regulating domestic pollution sources including ozone and particulate matter [1]. However, there are increasing threats from transboundary air pollutants such as Asian Dust and trace metals, which originate from neighboring countries [1,2]. At the same time, there is a need to consistently monitor and accumulate long-term data of greenhouse gases that cause climate change [1,3].

The South Korean government has been making efforts to monitor air pollutants and generate forecasting data by installing in-situ monitoring stations throughout the nation. In order to overcome the limited spatial coverage of the ground monitoring stations and to enhance the accuracy and speed of monitoring and forecasting air pollutants, the government plans to launch by 2018 a multipurpose geostationary satellite, which will be equipped with an environmental payload called the Geostationary Environmental Monitoring Satellite (GEMS) in addition to meteorological and ocean color monitoring capabilities [4,5].[1] The GEMS, coupled with in-situ ground level monitoring stations, is expected to improve domestic air quality monitoring and forecasting system [5]. The GEMS should also improve the capabilities to track the paths of transboundary pollutants and some "exceptional" plumes, which are either natural or anthropogenic. In addition, launching the geostationary environmental satellite will enhance the position of Korea as one of the leading nations in air quality monitoring and management.[2]

Space development programs such as the multipurpose geostationary satellite require a significant amount of public investment. To enhance the efficiency of government fiscal management over various large-scale public projects, it is important to

[1] The geostationary satellite is designed to operate in a geostationary orbit 35,790 km (22,240 statute miles) above the earth, thereby remaining stationary with respect to a point on the ground. The advanced spacecraft continuously views one-third of the earth, specifically the Pacific-Asia area, which includes Korea.

[2] The EUMETSAT/ESA (European Organization for the Exploitation of Meteorological Satellites/European Space Agency) of Europe and the National Aeronautics and Space Administration (NASA) of the U.S. are also currently pursuing geostationary environmental satellite projects similar to the Korea's GEMS program. EUMETSAT/ESA and Korea are planning to launch their respective satellites by year 2018.

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communicate the economic benefits of launching the GEMS with the governmental budgetary officials and the public at large [6,7].[3] Economic benefits provided by the GEMS project is the sum of the amount all members of society would be willing to pay for the information that will be generated by the project.

While the economic benefits of the GEMS project are of much interest, the process of measuring these values is less apparent as the services provided by the GEMS exhibit public-goods nature. The improved air quality information generated by geostationary satellite data can lead to public health benefits to the extent that the newly available information can influence individuals to modify their behaviors to avoid risks from exposure to air pollution.[4] As stated by Macauley [6] and Macauley and Laxminarayan [8], information will have more value when responsive actions can be taken accordingly.

The existing literature on valuing information from space satellite data has extensively applied cost savings approach to measure benefits from improved weather information for various applications: agricultural production and management, aviation industry, energy sector, and recreation activities [9–13]. The cost savings approach, which can be categorized as a physical linkage-based methodology, is commonly criticized for its lack of underlying utility maximizing economic theory [14].

As an alternative to the cost saving approach, we adopt contingent valuation method (CVM), which is suggested by Macauley [6].[5] CVM is the most widely used stated preference approach to place monetary values of a wide range of environmental goods and services [14]. To the best of our knowledge, our study is the first application of its kind to use CVM to measure the value of information (VOI) that arises from improving overall air pollution monitoring system, which is quite different from evaluating the effects of air quality improvement itself.[6] Applying CVM has advantages of measuring both use values by users of information and non-use values by the general public. For example, the general public may value the GEMS simply knowing that the national image of South Korea will be boosted by successfully launching the satellite, even if they do not immediately intend to use the information.

Thus, the objective of this study is to measure *ex ante* economic benefits of a space-derived earth science project in the form of improved information by using CVM. While designing the CV survey to reflect the unfamiliarity of the service being valued, i.e., improved information from the GEMS, we tried to take due care in defining the contingent commodity and in minimizing potential biases. This paper is organized as follows: Section 2 provides an overview of the current air pollution monitoring and forecasting system in Korea. Section 3 gives a detailed description of study design for the CVM and characteristics of the data. Section 4 presents the empirical results obtained from the CV responses regarding the GEMS project and the WTP measures for improved information from the earth science project. Section 5 summarizes the empirical findings and discusses research implications.

2. Air pollution monitoring and forecasting system in South Korea

2.1. Air pollution monitoring system

In 1979, the Ministry of Environment (MOE) of South Korea set the air pollution standard for sulfur dioxide (SO_2) to protect public health from air pollution and to maintain a pleasant living environment. Since then, MOE has extended environmental standards to other pollutants such as nitrogen oxide (NO_x), carbon monoxide (CO), ozone (O_3) and particulate matter of 10 μm or less (PM_{10}). The pollution standard has been revised and tightened over time [1]. As of 2009, the MOE and local governments in South Korea operated 283 ground stations nationwide to monitor air pollution levels, to obtain basic data for improvement of air quality, and to check the compliance to the pollution standard.

2.2. Air pollution forecast and warning system

The MOE forecasts the air pollution level for the next day using hourly measured air pollution levels and weather data. The Comprehensive Air Quality Index (CAI) [17] is then calculated using forecast data and released to the public [1]. As Table 1 shows, the CAI, ranging numerically from 0 to 500, is divided into six categories from A to F. The higher the CAI value is, the greater the level of air pollution is. The CAI is also indicated in different colors and pictograms to help the public easily understand the severity of air pollution. The MOE also provides information about the health and environmental effects of air pollution and gives useful advice that people can take to protect their health.

The CAI information about the air pollution levels, including O_3 and PM_{10}, are displayed on Air Korea, a MOE website that provides real time air pollution information, as well as on outdoor electronic display boards operated by local governments, so that the public can easily access the air quality information and its effects on their health. Since 2009, when the ozone forecast system went into effect in Korea, the forecast accuracy rate has been between 57% and 72% in seven major cities with an average of 65%. The PM_{10} forecast system provides forecasts twice a day: at 9 a.m. for the present day, and at 6 p.m. for the next day. The accuracy rate of the PM_{10} forecast was 62% on average in major cities in 2009; the accuracy rate for the present day (shown at 9 a.m.) was 68%, which was higher than that for the next day (6 p.m.) [1].

When O_3 or PM_{10} concentrations exceed a certain level, alerts are issued to help people minimize exposure to health risks. The O_3 alert system is divided into the three categories of “watch,” “warning,” and “serious warning,” which correspond respectively to the CAI categories of “unhealthy”, “very unhealthy”, and “hazardous”. Similarly, the PM_{10} alert system is divided into the categories of “watch” and “warning”, which correspond respectively to the CAI categories of “very unhealthy” and “hazardous”.

The occurrence and intensity of Asian Dust coming from China and Mongolia have significantly increased since the year 2000. From 2005 to 2009, Asian Dust occurred 15–21 days each year, causing adverse effects on various aspects of people’s lives. For

[3] In fact, the National Fiscal Act of South Korea requires benefit-cost analysis for public investment projects which require more than 50 million dollars of public spending. Economic valuation provides benefit estimates critical to this process.

[4] In addition to the potential effects on public health, according to the National Oceanic and Atmospheric Administration of the U.S.A. [12], social and economic benefits associated with improved information from GEMS can affect the following stakeholders through cost avoidance or increased value: (1) The nation as a whole, as it benefits from more informed policy decisions, (2) Local governments, which will be better off because they will be better able to comply with regulatory mandates by avoiding penalties, or, in some cases, additional costs of compliance, (3) Polluters, which will have more data to make the right decisions in cooperation with local governments, (4) Users of clean air, who will be able to better plan their infrastructure and better manage their operations, (5) The general public and more specifically sensitive groups, which will be able to better plan their daily activities and their spending patterns. New products and services will emerge to satisfy the need for clean air, outside, in the workplace, at home, and for personal enjoyment, (6) Individuals and services, which will be affected by the health-related impacts of air quality.

[5] Macauley [6] provides an excellent review of previous studies in measuring values of earth science information and potential use of CVM in this area.

[6] There are many studies measuring economic values of air quality changes using CVM in literature. Some recent works include Lee et al. [15] and Hammitt and Zhou [16].

Table 1
Categories of the Comprehensive Air Quality Index (CAI) used by the MOE of South Korea.

Category	Good	Moderate	Unhealthy for sensitive group	Unhealthy	Very unhealthy	Hazardous
CAI value ranges	0–50	51–100	101–150	151–250	251–350	351–500
O_3 (ppm)	0–0.04	0.041–0.08	0.081–0.12	0.121–0.30	0.301–0.50	>0.501
PM_{10} ($\mu g/m^3$/day)	0–30	31–80	81–120	121–200	201–300	301–600

example, elementary schools are closed during severe periods, many people suffer from respiratory diseases, and industries such as airlines, distribution and electronics are negatively affected. The alert information of O_3, PM_{10}, and Asian Dust is issued to the public through public media channels such as broadcasting, voice and fax devices, mobile phones, and electronic display boards.

2.3. Potential benefits from launching the GEMS

The air pollution monitoring systems currently deployed in South Korea and elsewhere is not capable of comprehensively monitoring transboundary air pollution as well as greenhouse gas emissions. The ground monitoring stations currently in operation to monitor and forecast air pollution levels in South Korea only cover their surrounding target areas. Low earth orbit (LEO) satellites used in advanced nations to monitor transboundary air pollution produce data once or twice a day with a limited coverage [18,19].

To improve the air pollution monitoring system, the South Korean government plans to launch the GEMS by year 2018. Synchronized with the earth's rotation, the satellite shall maintain a uniform position above the earth and cover the Asia-Pacific region including Korea. Circling the earth in a geosynchronous orbit, the GEMS should be able to effectively monitor transboundary air pollutants and greenhouse gas sources as well as domestic and conventional air pollutants, and thus generate continuous data streams necessary for intensive monitoring of concentration levels and transport paths of those air pollutants every 1 or 2 h [12]. In addition, the GEMS, which is equipped with a UV/Visible spectrometer, is expected to provide science data products with higher spatial and temporal resolution in monitoring SO_2, NO_2, O_3 and aerosols. The atmospheric scientists involved in the project estimate that the additional data products from the GEMS will enhance the forecasting accuracy rate of the air quality information by about 20% compared with the conventional approach using only the ground monitoring station measurement data.[7]

In this respect, the benefits to the public by implementing the GEMS project are not the reduction of health risks through improved air quality, as in terms of reduced mortality and morbidity, but the improvement in the "information" about air quality. Air pollutants such as O_3, PM_{10}, and Asian Dust are suspected to be linked to a variety of adverse health effects, which include asthma, bronchitis, increased respiratory distress symptoms and premature death from health complications [15,16,20]. With respect to policy changes to improve air quality, individuals may benefit from a certain environmental policy irrespective of whether they realize the air quality improvement or not. However, regarding a space project aimed at improving air pollution information, individuals may not enjoy potential benefits from the project unless they adjust their behaviors to avoid or alleviate the adverse effects from air pollution after getting access to the improved information [12,13]. Under the assumption that individuals may respond to improved air pollution information, they are expected to take voluntary averting behaviors, which may range from long term (e.g., where to live after retirement) to short term decisions (e.g., whether to engage in outdoor activities).

In addition to potential individual health benefits from improved air pollution information to the public, South Korea, as a nation, would receive economic benefits from the GEMS project. Accumulation of real time transboundary air pollution data will help the South Korean government effectively cope with possible environmental disputes with neighboring countries such as China and Japan, and international negotiations over the issue of climate change. Fig. 1 demonstrates the role of the GEMS in the air pollution forecasting process and the resulting potential benefits to the public by enhancing the accuracy and promptness of air quality information due to the GEMS project.

3. CVM study design

3.1. CV scenario and research design

CVM is a survey-based stated preference approach for placing monetary values of environmental goods and services not bought and sold in the market place [21–23]. A CV survey constructs a hypothetical market for the good being valued so that choices stated by survey respondents can be evaluated in a manner similar to the behaviors observed in actual markets. The basic components of a CV survey should include at least the following three aspects: description of the service being valued, how it will be provided, and the way it is paid for [21].

With no previous CV studies identified in measuring the value of information from a space project, we took due care in designing the CV scenario to understand technical aspects of earth sciences and roles of satellites on monitoring and forecasting system of air pollution, and then translate them into layman's terms. The survey design closely followed the recommendations made by the United States National Oceanic and Atmospheric Administration (NOAA) panel, which was in charge of evaluating the use of CVM for assessing the public's WTP [24].[8]

First, as indicated in Sections 2.1 and 2.2, current air pollution monitoring and forecasting system was described with visual aids of pictures of ground in-situ stations after an extensive consultation with earth scientists involved in the project. Then, to direct respondents' attention to the potential need of installing an

[7] There is uncertainty in the range of accuracy improvement in the air pollution information at this point because the GEMS project is still under development. However, a 20% accuracy improvement is the best available estimate we were able to acquire from the leading atmospheric scientists involved in the project.

[8] 20 years after the NOAA panel released their recommendations on how to properly conduct CV survey, Kling et al. [25], Carson [23] and Hausman [26] recently revisited and reviewed similar issues associated with the contingent valuation literature. Carson [23] and Kling et al. [25] indicated a careful but optimistic view of the welfare measures estimated from hypothetical CV responses, which satisfy various validity tests. On the other hand, Hausman [26] maintained a rather pessimistic view of obtaining a well-defined preference from hypothetical CV responses. These recent studies clearly emphasize the importance of realistically and accurately designing the CV scenario for the improved benefits from the GEMS project.

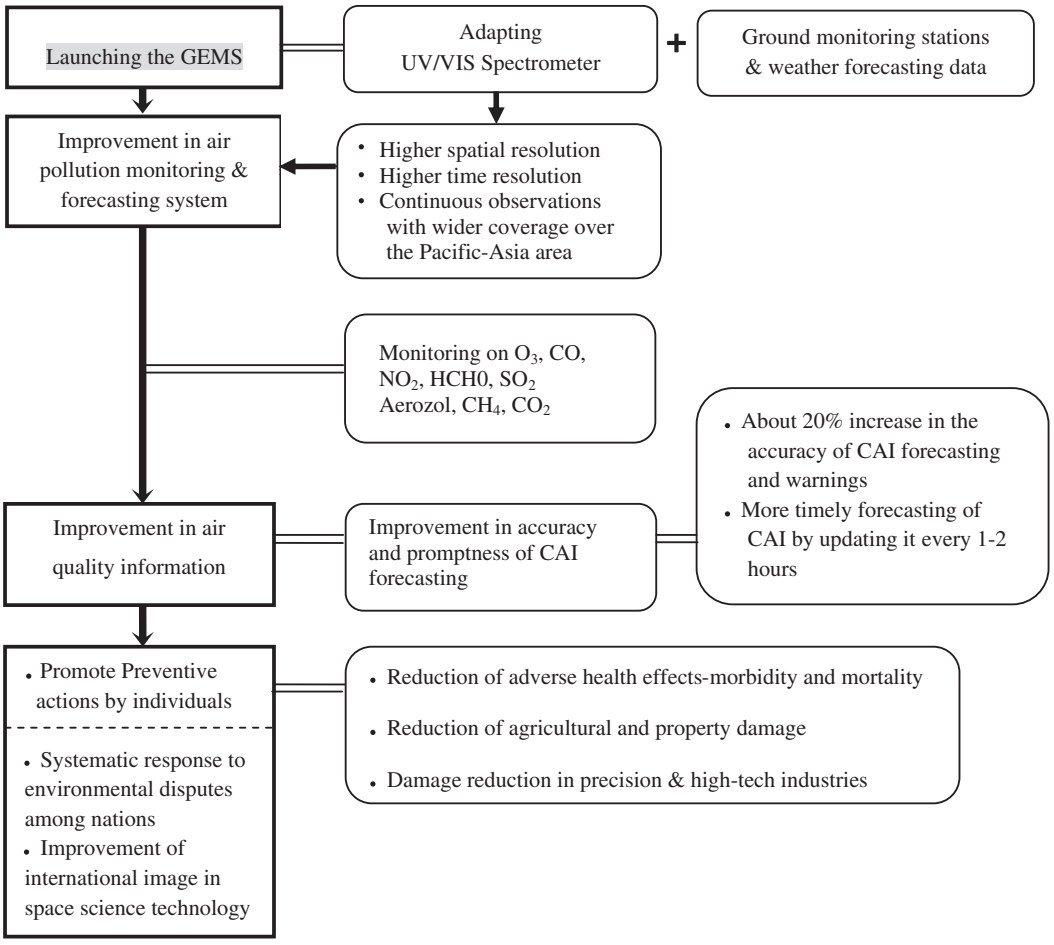

Fig. 1. The role of GEMS data in the air quality forecasting process and socioeconomic benefits from the GEMS project.

environmental satellite, we illustrated the limitations of current monitoring system in accurately forecasting the trans-boundary air pollution and climate changes. Subsequently, the South Korean government's plan to launch the GEMS was introduced with pictures of earth-observing satellites and positions of geostationary satellites circling earth during the day. By generating data products with high spatial and temporal resolution in wider range, the GEMS will enable to better track the origin and paths of transboundary as well as domestic air pollutants, and accumulate long-term time series data surrounding the Korean Peninsula.

As we illustrated in detail in Section 2.3 and Fig. 1, about 20% increase in accuracy and promptness of CAI by launching the GEMS is the service to be valued in the constructed CV scenario. If individuals utilize the information and alter their activities, then they may enjoy use values as reflected in the reduction of damages from their health and properties. In addition to these use value components, individuals may have non-use values to the extent that South Korea as a nation may be able to systematically cope with environmental disputes among neighboring nations and therefore improve the national image as an advanced country in the field of aerospace science technology. The CV question in this study captures a total value including use as well as non-use values from launching the GEMS.

To facilitate respondents' ability to comprehend CV scenario constructed, a three page information sheet was presented using carefully screened layman's terms coupled with examples and several visual aids to describe the potential needs of the GEMS project, its main mission, and potential benefits on individuals. The respondents were then asked the single-bounded dichotomous choice WTP question–if they would be willing to pay the suggested amount for the improved information on air quality, taking into account their current income levels. Since improved air quality information provided by the GEMS project can be regarded as a public good, a natural choice for the payment vehicle is an additional tax. The tax revenue collected on a household basis will be deposited into a public fund called the "space science development fund", and solely be used for the GEMS project.

As an alternative payment vehicle, we devised a more personalized payment mechanism reflecting the availability of a recent short message service from several regional environmental agencies. The improved local air quality information generated from the GEMS will be provided via the cell phone text message service.[9] As is the case with the tax scheme, family members of those who are willing to pay the additional fee for text message services are allowed to receive the information free of charge. Those fees from cell phones will also be deposited into the space fund to support the space-derived earth science project. The six different bid points ranging from US $0.26 to US $1.72 per

[9] Some parts of South Korea, including the Seoul metropolitan area, have already started text message service to inform the CAI and air pollution alerts and warnings. Thus, cell phone messages can serve as a realistic payment vehicle for eliciting individuals' WTP for environmental information.

household are randomly assigned to the respondents in the sample.[10] The payment frequency is designed to be monthly to be in accordance with the cell phone bill payment scheme.

Before asking the CV question, we collected extensive information on individuals' attitudes toward the accuracy of current air quality monitoring systems and their perceptions about health risks from air pollution. After the CV question, respondents were also asked to evaluate the degree of credibility of the CV scenario in terms of 20% improvement of air quality information. The survey concluded by compiling the socioeconomic information of respondents, including income, gender, age, education, and occupation.

3.2. Survey design and data

After a thorough examination by atmospheric scientists, CV survey questions were further reviewed by two focus groups. The questions were also pretested with 100 potential respondents, which provided information on the expected distribution of WTP. An in-person household survey of 1000 randomly selected residents throughout the nation was conducted in November 2009. The survey was conducted by trained interviewers in one of the leading professional research firms in South Korea with substantial experience in conducting CV surveys. The sample of residents over twenty-five years old (excluding students) was allocated across major cities in South Korea according to age and gender distribution. The 1000 respondents were divided into two groups of 500 according to the two payment vehicles.

The cooperation rate, defined as the number of interviews that were completed once respondents met the screening criteria, was approximately 53%. Of the 1000 respondents who completed the CV survey, about 35% were willing to pay for the improved air pollution forecasting information. For the respondents who were unwilling to pay any money for the improved information, the main reason of their unwillingness was that the government should finance the project with the tax or cell phone bills that they had already paid.

Table 2 defines selected individual characteristics and other variables used as covariates to estimating WTP functions. We elicited respondents' subjective attitudes toward health risk from air pollution (APHRisk) on a Likert scale from 1 to 11, with 1 implying "no risk" and 11 implying "very serious risk." Respondents seemed to feel that exposure to air pollutants would pose considerable health risks, including respiratory diseases, with an average seriousness index of 7.9. In addition, we elicited respondents' subjective perceptions about the accuracy of the current air quality information system (AQIAccuracy) on a scale from 0 to 100. Respondents appeared to feel that the current air pollution monitoring and forecasting system provides fairly accurate air quality information, with an average of 62.4 points. This subjective perception of the accuracy of information was within the rage of the objective forecasting accuracy rate reported by the MOE, 57–72%, as indicated earlier. More than 90% of respondents thought that the satellite would be able to achieve the 20% accuracy improvement given in the CV scenario. Sixty four percent of respondents agreed that the government should make more aggressive investments in space satellite projects.

4. Empirical results

4.1. Estimation results

Table 3 reports the probit estimates from the three model specifications to explain the respondents' intentions to support the space project.[11] The most generalized specification as labeled Model (3) includes an experimental design variable of payment vehicle, covariates of respondents' attitude and socioeconomic variables as well as bid amount and household income variables. Observing how these covariates influence the tendency of saying 'yes' in dichotomous choice question will help us gain information on the validity of the hypothetical nature of CVM [21,24].

The bid amount presented to the respondents (BID) exhibited negative signs across all model specifications, indicating that the tendency for giving positive responses diminished with the offered bid amount. Respondents with higher income (MIncome) were more likely to express their support for the project, which imply that air quality information is a normal good. The PVehicle variable indicated significant positive signs in Models (2) and (3), demonstrating that the payment vehicles have different effects on respondents' intentions. This positive sign implies that the personalized payment vehicle, i.e., the additional fee for cell phone bill, may elicit a lower WTP for the improved information from the GEMS than the collective charges for the space fund. One possible explanation for this result is that respondents who were assigned with additional cell phone bills were more likely based on use values of improved information for their households in responding to the CV question. On the other hand, respondents who were assigned with additional tax probably attached non-use value to other people in the society and to the nation as a whole as well as use values to their households from improved information.

Overall, most covariates included in Model (3) had significant effects on intentions to support the GEMS project with expected signs. The subjective attitude toward accuracy of air quality information, measured by the AQIAccuracy variable, had negative impacts on the probability of expressing a positive response to the given bid amount. In other words, as respondents perceive that the current air quality monitoring system is accurate enough, they seemed to be less inclined to express WTP for improved information gained by launching the GEMS. Equally important, the subjective beliefs on health risks from air pollutants (APHRisk) had a significant positive influence on the CV response. This means that respondents who feel that air pollution may pose considerable health risks were more likely to give positive responses to the proposed environmental space project. As expected, respondents' attitudes toward public investment for space development program in general, ESInvestment, also had a positive impact on the stated preference for the GEMS. Respondents with more children were more likely to express their support for the project. Respondents who receive regular health check-ups (as a type of protective activity) were also more inclined to respond positively to the given bid amount.

4.2. Willingness to pay for improved information

Mean WTP for improved information from the GEMS project were calculated using the parameter estimates of the probit models shown in Table 3 [27]. The nature of improved information is about 20% increase in the accuracy of CAI forecasting. Table 4 shows empirical WTP distributions generated at the mean of covariates according to the Krinksy–Robb procedure. The annual mean WTP per household was stable at about US $3.70 for Models (1), (2) and (3). The median WTP estimates were very similar to the means,

[10] The exchange rate was 1160 Korean won per US $1 at the time of the survey (November, 2009).

[11] The CV responses to the dichotomous choice question for the improved information can be illustrated in the framework of a random utility model (RUM) suggested by Hanemann [27]. Technical descriptions of RUM in the form of probit model are available from authors. Probit models were estimated using LIMDEP version 9.0 [28].

Table 2
Definitions of Variables and Sample Characteristics.

Variable Name	Description	Mean (S.D.)
Experimental design variables		
BID	The amount of charge presented in the CV scenario (US $)	0.85 (0.48)
PVehicle	=1 if payment vehicle was monthly charges for a space science fund; =0 for monthly fee for text-message service of cell phone	0.5 (0.5)
Attitudinal variables		
AQIAccuracy	Subjective perception about the accuracy of the current CAI information system, on a 1–100 scale	62.4 (16.6)
APHRisk	1–10 seriousness index of health risk from exposure to air pollutants	7.9 (1.4)
ESInvestment	=1 if respondents think that more public funds should be allocated to the space projects; =0 otherwise	0.64 (0.48)
Socio-demographic variables		
MIncome	Household's monthly income before tax in 2008 (in 1000 US$)	3.148 (1.401)
# of Children	Numbers of children under age 13	0.41 (0.439)
HCheck	=1 if the respondent receives regular medical checkup; =0 otherwise	0.37 (0.48)

indicating that the WTP distributions are well balanced around the mean values due to the relatively small standard errors.

4.3. Ex ante economic evaluation of the GEMS project

To answer the question whether the WTP estimates shown in Table 4 are large enough to support the earth science project, the annual WTP needed to be aggregated to the population. Since information generated from the GEMS data is close to pure public goods, geographic extent of the market for services from the GEMS project may be the entire households of South Korea. That is, potential annual benefits of improved information from launching the GEMS can be calculated by multiplying the mean WTP estimates from Table 4 by a total of 15,988,275 households in 2009. Therefore, the present value of total benefits, discounted at annual discount rate of 5.5%, are expected to be ranged from $321 million to $325 million over the 10-year lifetime of the GEMS once it is launched into the orbit in 2018.

As indicated earlier, the GEMS is a part of a multipurpose geostationary satellite of meteorological and marine as well as environmental satellite payloads. MOE suggested evaluating the cost of each instrument separately in the cost-benefit analysis. The total cost of operating the GEMS includes initial project costs of R&D expenditures and construction costs, and maintenance costs over the service period. The present value of the cost of the GEMS project is approximately estimated to be around $117 million [30]. Based on the present values for the benefit and cost estimates, the benefit cost ratio for the GEMS project turned out to be about 2.77. This means that the total economic benefit from launching the earth science project far exceeds the total cost required for the implementation of the project. Therefore, the economic feasibility analysis derived from the benefit estimates based on VOI approach using CVM shows that the GEMS project is economically viable.

Table 3
Probit Estimates of Dichotomous Choice CV Responses.[a]

	Model 1	Model 2	Model 3
Intercept	0.089 (0.674)	−0.0343 (−0.247)	−0.553 (−1.617)
Bids	−0.863 (−9.248)	−0.872 (−9.280)	−0.895 (−9.336)
Payment Vehicle		0.266 (3.118)	0.0.259 (2.991)
Attitudinal variables			
AQIAccuracy			−0.0047 (−1.825)
APHRisk			0.060 (1.875)
ESInvestment			0.314 (3.387)
Socio-demographic variables			
MIncome	0.0571 (1.777)	0.0554 (1.704)	0.056 (1.647)
# of Children			0.179 (3.047)
HCheck			0.180 (2.015)
N	1000	1000	1000
χ^2 statistic	96.3	106.0	141.4

[a] The numbers in parentheses below the estimated coefficients are the ratios of the estimated coefficient to the estimated standard error, χ^2 denotes the statistic that the null hypothesis that none of the independent variables affects the CV responses.

Table 4
Distribution of annual WTP estimates for improved information. Unit: US dollars.

Quantile	Model 1	Model 2	Model 3
Lower 2.5%	1.78	1.86	1.82
Median	3.72	3.78	3.78
Mean	3.67[a] (0.86)[b]	3.72 (0.84)	3.71 (0.74)
Upper 2.5%	5.16	5.14	5.18

[a] Annual WTP was obtained by multiplying the monthly WTP calculated using parameters of probit models of Table 2 by 12.
[b] Standard deviations of mean WTP estimates in parentheses. These are calculated from the Krinsky–Robb [29] approximation of the empirical WTP distributions.

5. Concluding remarks

This paper applied the CVM in measuring potential economic values of an improved air pollution monitoring and forecasting system that will utilize data products from an environmental geostationary satellite payload, which the South Korean government is pursuing to launch by 2018. This particular CVM application is different from previous CV studies in the sense that we did not evaluate policy changes that may result in improvement of air quality itself, but evaluated the benefits from value of information that may arise from a space satellite project. Due to the lack of a similar CV study in valuing space-derived earth science information, we exerted extensive efforts in designing an appropriate contingent commodity to collect credible survey data.

Empirical results from the survey data from 1000 randomly selected households suggest that relevant attitudinal and demographic variables as well as economic variables (i.e., BID and MIncome) have significant effects, with expected signs, on WTP for improved air pollution information from the GEMS project. Mean WTP was stable at around US $3.70 per year for improving accuracy of the CAI forecast information from the GEMS project across all model specifications. This WTP estimate was large enough so that an *ex ante* benefit cost analysis reveals the total economic benefit from the project exceeding the total cost. The result strongly implies that the project is economically feasible.

The results of this study provide insights for academic research and policy design. From a research perspective, this study exhibited the possibility of using the CVM as an alternative approach in estimating the VOI from a space satellite project. To the extent that

improved air quality information facilitates individuals to make better decisions in trying to reduce adverse health effects, our finding that individuals are willing to pay a considerable amount for the improved environmental information will provide useful insights to policy makers towards introducing environmental information programs as an effective environmental management strategy.

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