Social Benefits of Environmental Information from Geostationary Environmental Monitoring Satellite (GEMS): Incorporating Payment Vehicle Effects

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Abstract

This paper is to measure ex ante economic values of environmental information arising from improved air quality monitoring and forecasting capabilities by enabling to use data products from GEMS as payload of a multi-purpose geostationary satellite, which Korean government is pursuing to develop. In addition, this paper is to empirically test the payment vehicle effects on individuals' stated WTP. The two payment vehicles comprise a coercive charge with possible free-riding incentives (underbids) and a personalized fee with no free-riding.

Empirical results, which are estimated using a survey data from 1,000 households, suggest that relevant attitudinal and demographic variables as well as economic variable had significant effects on WTP for environmental information. However, on the contrary to our expectation, the coefficient of personalized payment vehicle had significant negative sign without apparent payment vehicle bias. This implies that elicited WTP would be lower under a personalized fee than under a coercive charge. In fact, annual mean WTP of sub-sample with additional fee for text message service of cell phone ($1.93 to $2.01) counted only 40% of those of sub-group with additional charge as an objective tax ($5.14 to $5.48).

I. Introduction

While air quality in Korea has been steadily improved due to Korean government's aggressive initiatives and the public's active participation, there are increasing threats from trans-boundary air pollutants such as yellow dust, sulfur, carbon and trace metal, which were transported from neighboring countries including China and other developing Asian countries. As an alternative to monitor regional transport events in addition to improve domestic air quality monitoring and forecasting system, Korean government is planning to launch a multi-purpose geostationary satellite by 2017.[1] As a continuation of COMS(Communication, Ocean Color and Meteorology Satellite) which has been planned to launch at 2010 and to end its life in 2017, the forthcoming multi-purpose geostationary satellite will load an environmental payload in addition to the currently planned meteorological and ocean color monitoring mission (Chang, 2008; Kim, 2009).[2] Coupled with in-situ ground level monitoring stations, Geostationary Environmental Monitoring Satellite (GEMS) will support the mission of improving monitoring of SO_2, NO_2, O_3 and aerosol using UV/Visible spectrometer from Geostationary Orbit, and consequently enhance the forecasting of air quality (Kim, 2009).

Space development programs such launching multi-purpose geostationary satellite represents a significant investment. Therefore, Korean government directed to conduct a benefit-cost analysis and to review the economic feasibility of this large scale of public investment. As part of benefit-cost analysis of the space program, this paper is focused on measuring ex ante social benefits of loading GEMS as a payload of the multi-purpose satellite.

Data products and applications of GEMS could have the potential to affect a vast of human activities by improving air quality monitoring and forecasting capabilities. For example, the massive yellow dust can have devastating impacts including the deterioration of respiratory disorder to the sensitive groups, the damage to agricultural crops and buildings, and disruption of operation on high-tech facilities. While improved information as to the traveling path and intensity of those trans-boundary air pollutants is of obvious interest, estimation of the economic value of that environmental information is not so obvious.

Economic values of GEMS project may arise from the changes in stakeholders' activities in response to information from improved air quality monitoring and forecasting. Because of the widespread impact of air quality on a broad range of decisions, there are several stakeholder groups who will economically benefits from enhanced air quality monitoring and forecasts. Those groups ranged from individuals, industries, local cities and counties, and to the nation as

a whole.[3] This paper will focus on measuring economic values of improved environmental information from general public's perspectives.

Information about air quality can affect individuals in various aspects, including adjusting daily life to reduce adverse health effects, improve quality of life and reduce property damages so on (Holt et al., 2006). Most of those effects are intangible and should be evaluated before the satellite is indeed launched into the orbit. Therefore, the contingent valuation method is applied to measure the economic value of environmental information from GEMS. To our knowledge, this is the first study of measuring value of environmental information about air quality changes, which might be quite different from valuing effects of changes in air quality itself. Thus, we spent a great deal of time in defining the contingent commodity being valued as well as selecting an appropriate payment vehicle. In addition to a mandatory charge in a form of an objective tax, which commonly used in CVM studies of public goods, we adopted another voluntary and personalized charge—additional fee of text message service of cell phone bill.

The paper is organized as follows. Section 2 gives a detailed description of CV survey design and data collection process. Section 3 presents empirical results of single-bounded dichotonomous choice CV response. Section 4 concludes with a discussion of the implications of empirical findings and directions for further work

II. CV Study Design and Survey Data

1. Construction of an effective Contingent Valuation Scenario

To present the services from GEMS on individuals effectively, we presented three pages of information sheets describing the potential needs of launching GEMS and it's main function, and expected impact so on with visual aids. With no previous CV study identified in this subject, we spent a great deal of time in understanding scientific knowledge and transforming them into layman's term. Defining the services to be valued followed the following process.

Public investment decision on launching GEMS

GEMS(Geostationary Environmental Monitoring Satellite) is a payload of a multi-purpose geostationary satellite which is planned to be launched no later than 2017. GEMS will deliver data products that will enhance and improve monitoring and forecasting of air quality over Asia (of course including Korea) by providing air chemical species measurements with high temporal

resolution over Asia; by enabling to monitor regional transport events such as trans-boundary transport of pollution and Asian dust; and by to enhance our understanding on interactions between air chemistry and meteorology (Kim, 2009).

Potential services from GEMS

Monitoring and forecasting of air quality in Korea has been mainly based on the data from in-situ ground measurement stations located in cities throughout the nation and satellite data provided by foreign countries such as USA and Japan. Based on the air quality monitoring information, major cities published 24-hour air quality forecasts and alert the public to air pollution conditions or the onset, severity and duration of poor air quality.

Data products from GEMS coupled with those from in-situ ground measurement stations will provide more complete, timely and more reliable information about air quality. The better data with higher spatial and temporal resolutions from future GEMS is expected to generate the more accurate air quality models and the better the timing and extent of warnings and mitigating actions. The instruments and services of GEMS will have economic values to extent that the information provided by the satellite can enable the quality of decisions made by stakeholders. The potential function of GEMS is to complement and enhance existing in-situ observations by providing column integrated concentration observations, and thus improve the in monitoring and forecasting air quality (Kim et l., 2008). Those potential service flows that may be provided from GEMS are summarized as follows in Table 1.

<Table 1> Potential services that will be provided by data products from GEMS

Type of Services		Potential Improvement
Increase frequency and accuracy of air quality Monitoring	Domestic	· Complements ground measurement by adding information · Provide daily map and long-term air pollution trends ·Provide information to validates and improve air quality modeling
	Trans-boundary	· Provide global picture and long-term homogeneous AQ monitoring throughout the Pacific-Asia · Provide tracks and map of long-range trans-boundary air pollution and ocean pollution, so we relied on foreign satellite data
Enhance the accuracy of air quality forecasting		·Improve accuracy of air quality forecasting ·Provide Pacific-Asia air quality forecasting services to wide range of regions · Provide inputs to weather forecast model for middle range terms

The concentration level of the major pollutants (SO_2,NO_2,CO ,O_3,PM, so on) are measured in more than 200 hundreds ground-level monitoring centers across the country. These raw measurements for each pollutant are announced to the public on a real time basis. These raw

measurements are then converted into CAI(comprehensive air quality index) values using standard formulas developed by Ministry of Environment.[4] In larger cities, state and local agencies are required to report the CAI to the public daily. The most of metropolitan re in Korea also provide forecasts for the next day's CAI. If CAI for main air pollutants (including O3, PM and Yellow dust) are above certain numbers, Korean government and local officials is asked to issue air pollution warnings.

Compared with the situation of using ground measurement data, data products from GEMS are expected and improve the accuracy of CAI approximately by 20%, and to enhance the frequency of CAI release to the public.

Potential Effects on the public

The improved information about air quality is assumed to trigger stakeholders to change their behavior or decisions to avoid the adverse effects associated with 'poor' air quality. Especially, some pollutants (such as O_3, PM and Yellow dusts) are suspected to be linked to variety of adverse health effects, including premature death, asthma, bronchitis, increased respiratory distress symptoms so on. Certain populations are especially vulnerable to adverse health effects, including children, the elderly, pregnant women, and those with pre-existing cardio-respiratory disease. The forecasts and warnings system is assumed to motivate industry decision makers and general public to take mitigating activities voluntarily. For example, Industry and individual decisions based on air quality monitoring and forecasts range from long-term decisions (e.g., specifications of a new plant and where to live in retirement) to short-term decisions (e.g., what level to run the factory or go to work or not on a poor air quality day).

As indicated it earlier, it is notable that the contingent commodity being valued here is not changes in adverse health effects (in terms of reduction in mortality and morbidity risk) from changes in air quality, but improvement in information about air quality. If government successfully implements a policy to improve ambient air quality level, individuals could have benefits of reduced health risks whether they realize it or not. However, the benefits from improved information about local air quality from GEMS may not be fully realized unless individuals utilize the information and incorporate them in their decision makings.

Besides the potential benefits of having improved information, respondents were present with additional effects of securing independent data products from GEMS. Accumulating the real time data associated with trans-boundary air pollutants will help our government to systematically cope with possible environmental conflicts among neighboring countries

including China and Japan. Moreover, because it is the first attempt in the world to load a specialized environmental satellite,[5] GEMS, Korea's national image will boost up to position the country as a leader in air quality issues, if this space project is succeed on time**.**

CV question

Following questions eliciting respondents' attitudes of and subjective perceptions about the accuracy of current air quality monitoring and forecasting system and perceptions about health risk from air pollution, respondents were presented with three pages of sheets describing various aspects of the space project. After reminding respondents to consider their household income and expenditures, respondents were asked if they would be willing to pay for the suggested amount for the space project. Following NOAA panel's recommendation to secure the incentive compatibility, a single-bounded closed-ended question format was used with six different bid points ranging from 26 cents to $1.72 per household and month.[6] After the WTP question, follow-up debriefing questions were asked to identify reasons for unwillingness to pay or some form of protest. After those debriefing questions, respondents were also asked to evaluate the degree of credibility of the CV scenario, especially in terms of the accuracy increase of air quality information if GEMS were successfully launched.

Payment Vehicle and Potential Strategic Behavior

Since services or information that will be provided from GEMS is considered to be a pure public good. Thus it is natural to suppose that the government will fund the project of launching the multi-purpose geostationary satellite including GEMS payload. Therefore, the payment vehicle chosen in the first round of CV questionnaire was additional annual charges, which will be deposited in a public fund (e.g., a space science development fund) and will be solely used to support the GEMS project and provide environmental information including local air quality forecast and alert. However, several participants in the two focus group discussions, which were held to test the draft of CV questionnaire, rejected the payment mechanism of collecting additional charges for the project. They felt that one of the main purposes of collecting taxes in the government should be to provide public goods such as developing space projects. A pretest with 100 potential respondents using an open-ended question for WTP exhibited similar results to the extent that more than a half of the respondents (54%) were not willing to pay for the improved information from GMES at all. About 60% of those of who were not willing to pay

indicated that the fund for launching GEMS should be provided from the existing government revenue.

We interpreted these high non-responses as an indication of respondents' hostilities to the coercive and mandatory charges (Hackl et al., 2005, Morrison et al., 2000). Another possible interpretation might be related to respondents' strategic behavior in a form of free riding. That is, respondents might understate their 'truthful WTP' because they believed that they might have actually to pay the amount they expressed (Hackl et al., 2005; Wiser, 2007).[7] At the time of designing the CV questionnaire, there was intensive publicity around the Korea's first attempt at putting a satellite into orbit. The launch of NARO satellite was scheduled at June 2009.[8] However, the attempt has been cancelled and delayed twice before it launched at the NARO Space Center at the end of August 2009 without success. Perhaps, the media spotlight about the NARO satellite launching program prompted respondents to believe that the government must put higher priority to the space development programs. Respondents seemed to believe that the CV scenario of launching GEMS and fund raising plans may be a high priority project so that the government would be likely to pay for the GEMS from existing revenue. In this regards, respondents may not feel that they should have to pay for GEMS through the increased charges, leading to low participation rates for positive willingness to pay (WTP).

As an effort to increase the participation rate on CV question, we devised another more personalized payment mechanism in addition to the mandatory and collective charge. The improved local air quality information generated from GEMS will be transmitted to the respondents by their cell phone text message service. If the respondent is willing to pay for the additional charge for text message service of cell phones, the rest of the family may receive the environmental information service with free of charge. Those additional charges for cell phone bill will be deposited into a fund to support the space. Hoping that the personalized payment vehicle will ease up the free riding effects, we anticipated that stated WTP under personalized charges will be higher than elicited WTP under the coercive and collective charge.

2. **Survey design and data**

As part of economic analysis associated with the public investment to improve air quality monitoring and forecasting, an in-person household survey of 1,000 randomly-selected residents throughout the nation was conducted during November of 2009. The sample of residents over 25 years old (excluding students) were allocated across major cities according to

age and gender distribution of the sampling area. The survey design closely followed the recommendations made by NOAA panel charged with evaluating the use of stated preference methods for assessing the public's willingness to pay (Arrow et al., 1993). The CV survey question was reviewed by two focus groups and was pretested with 100 potential respondents, which provided information on the expected distribution of WTP.

Reflecting the two different payment vehicles, we designed two versions of CV question. Type A version used monthly charges for the space science fund as the payment vehicle. On the other hand, Type B version used monthly charges for text message services of cell phone bill as the payment vehicle. The payment frequency for charges was designed to be monthly, not annually, to be in accordance with the cell phone bill payment scheme. The five-year payment term was established to make clear that this wouldn't be involved in an indefinite funding obligation. The whole sample was split into two groups with 500 respondents for each group. Within these two independent samples, each sub-sample is split into two groups again depending on respondents' health status. 30% of the sample in each group was allocated for sensitive groups of population, who have experience of respiratory diseases and/or are elderly people over 60 years old. Cooperation rate (defined as he number of interviews that were completed once respondents met the screening criteria) were approximately 43%. Information was collected on respondents' attitudes toward environmental pollution including air pollution, subjective perceptions about the accuracy of and other economic and demographic characteristics. Table 2 defines the variables used in the analysis and provides summary statistics.

III. **Empirical Results**.

Table 3 reports parameter estimates for several specifications of the random utility model describing respondents' intentions to support the space program in a form of single-bounded dichotonomous choice, which was estimated via maximum likelihood estimation using LIMDEP Version 9.0. Model 1 is specified to test the existence of payment vehicle effects as well as the impacts of attitudinal and demographic variables on WTP for improved environmental information, whereas Model 2-3 added covariates which may detect payment vehicle bias rather than payment vehicle effects. In addition to an additive variable for payment

vehicle, an interactive term with payment vehicle was included in the probit models of Model 2 and 3.

Overall, most explanatory variables included significantly influenced WTP function with expected signs.[9] As expected, the results presented the negative signs for the BID variable across all the model specifications, indicating that the tendency for the 'yes' responses diminishes with the offered bid amount. The subjective attitude toward accuracy about the current air pollution forecast and warning system had negative impacts on the probability of saying yes to given bid amount. In other words, as respondents think that the current forecast and warning system works well, they seemed to be less inclined to be willing to pay for improving information by launching GEMS. Equally important, the subjective perception of health risks from air pollutants had a significant positive influence on WTP. As expected, respondents' attitudes toward public investment for space development program in general have also positive impact on the stated preference for launching GEMS. Higher income group of respondents with more children were more likely to express their support for the project. Respondents who get regular health check-up were also more inclined to say yes to specified bid amount.

To empirically test payment vehicle effects and potential bias, we include an additive dummy variable for payment vehicle (Model 1) and interaction terms between payment vehicle variable (PVEHICLE) and variables associated with respondents' attitudes (Model 2) and work status (Model 3). A variable reflecting respondent' belief about the credibility of CV scenario was included because of the expectation that respondents who received the personalized payment vehicle (charges for text message service) might be more sensitive to the possibility of realization of CV scenario before they answered the CV question. If the case, the interactive variable with CVSAGREE could have a positive sign. Likewise non-working respondents may be inclined to 'free-ride' with the payment vehicle of collective charges and say yes to a higher bid than they otherwise would be willing to pay, and thus the interactive variable with NWORK could have a negative coefficient.

To our surprise, the probit estimation results were contrary to our expectation in that the PVEHCILE variable had significant negative sign, implying that personalized payment scheme elicits a lower WTP for the improved information from GEMS. While the beliefs toward CV scenario (CVAGREE) seemed to induce respondents to say 'yes' to the valuation question, the interactive term was not significant implying no significant payment vehicle bias. On the other

hand, respondents' working status did not have significant influence on the WTP in neither additive nor interactive term.

Using the parameter estimates of probit models reported in Table 3, welfare measures of improved information from GEMS are presented at the bottom of Table 3. As indicated earlier, the source of improvement in information arises from the 20% increase in the accuracy of air quality monitoring and therefore air quality forecasting. WTP estimates were stable across model specifications but were quite different according to the treatment of payment vehicle. When applied to the entire sample without differentiating the payment vehicle effects, annual mean WTP ranged from $3.54 to $3.74, which may suggest that there is no apparent payment vehicle bias. However, when welfare measures were calculated only for Type A group (i.e., PVehicle=0), annual mean WTP ranged from $5.14 to $5.48. On the contrary, for Type B group (i.e., PVehicle=1), annual mean WTP ranged from $1.93 to $2.01, which counts only about 40% of WTP for the group Type A.

IV. Concluding Remarks

The main objective of this paper was to measure the potential economic values of improved air quality monitoring and forecasting capabilities arising data products from GEMS as a payload of a multi-purpose geostationary satellite, which Korean government is pursuing to develop. In addition, this paper is to empirically test the hypothesis that individuals' stated WTP for public goods differ based on the way in which the good is funded. The two payment vehicles comprise a coercive charge with possible free-riding incentives (overbidding) and a personalized fee without free-riding incentives.

Due to lack of similar case of non-market valuation, our contingent valuation study put an extensive effort in designing a plausible and credible CV questionnaire. Empirical results, which are estimated using a survey data from 1,000 randomly-selected households, suggest that relevant attitudinal and demographic variables as well as economic variable (BID and MINCOME) had significant effects on WTP for improved environmental information. However, to the contrary to what we anticipated it, the coefficient of a dummy variable representing the payment vehicle of personalized fee had significant negative sign regardless of model specifications, while there appeared to be no apparent payment vehicle bias. This implies that elicited WTP would be lower under a personalized fee than under a coercive charge. In fact, Mean WTP of the sub-sample with additional fee for text message service of

cell phone ($1.93 to $2.01) counted only 40% of those of the sub-group with additional charge as an objective tax ($5.14 to $5.48). We are in the process of finding an explanation for this finding

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Footnotes

[1] Geostationary satellite is designed to operate in 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 view one-third of the earth, the Pacific-Asia area including Korea.

[2] The highly advanced COMS satellite will have three payloads; one for meteorology, one for ocean observation and one for communications. COMS will provide meteorology data to end-users around the globe, oceanography data for the Korean peninsula and experimental communications services in Ka-band. COMS is Korea's first geostationary satellite and will provide Korea with its own meteorology and ocean data thus giving increased independence. COMS is part of a 15-year Korean space plan begun in the 1990s, and followed systematically ever since.

[3] Social benefits associated stakeholders are the following: (1) the nation as a whole benefits form more informed policy decisions. (2) local governments will be better off by utilizing the information to better comply to ME standards, avoiding penalties (3) "polluters" will have more data to make the right decisions in cooperation with local governments (4) users of clean air will be able to better plan their infrastructure and better manage their operations (5) The general public and more specifically sensitive groups 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 affected by the health related impacts of air quality (NOAA, 2007).

[4] As an effort of release information about air quality as easy as to understand as the weather forecast, ME constructed an index of reporting daily air quality, the health concerns for different levels f air pollution, and how individuals can protect their health when pollutants reach unhealthy levels. CAI, which is calculated for five major air pollutants (So2, No2, CO, PM, O3), is measured on the linear scale groups ranging from 0 to 500 with specific color for each CAI category. The higher the CAI value represents the greater the level of air pollution with the greater the health concern. Since this study is not intended to evaluate changes in air quality, but the system Our CV survey questionnaire did not make direct connection to the CAI, but did explain that the information from GEMS will improve the frequency and accuracy of monitoring and forecast of air quality.

[5] At the same time framework, NASA in USA and ESA (European Space Agency) in EU are also preceding a similar project to Korea's GEMS program. However, GEMS of Korea will be the first geostationary environmental payload launched into orbit if the launching time schedule is met on time.

[6] At the exchange rate (1,160won/US$1) when the survey was conducted (November 2009).

[7] In many CV studies, the free-riding effect seemed to occur in two directions. Beside the potential for underbid, respondent may overstate if they believe they may not need to pay their WTP but hope to influence the provision of the public good at issue (Carson et al.)

[8] Since 1992, Korea developed and launched several satellite systems and rockets overseas such as the solid fueled KSR-1 and KSR-2 Sounding Rockets. The NARO satellite was the first attempt to be launched within the Korean territory (naver.com).

[9] Respondents' health status was used as an experimental design with allocating 30% of the sample to respondents who have experience some sort of chronic respiratory disorder. However, the variable associated with respondents' health status was not significant in any specification of WTP function. Thus, the variable was not included in the estimation of probit models as reported in Table 3.

<Table 2> Definitions of Variables and Sample Characteristics

Variable Name	Description	Mean(S.D)
BID	The amount of charges presented in the CV scenario ($)	0.85 (0.48)
PVehicle	=1 if payment vehicle was monthly fee for text message service of cell phone; 0 for monthly charges for a space science fund;	0.5 (0.5)
Attitudinal Variables		
AQIAccuracy	Subjective perceptions about the accuracy of the current CAI information system on the 1-100 scale	62.4 (16.6)
APRisk	1 to 10 seriousness index of health risk from exposure to air pollutants	7.9 (1.4)
ESInvestment	=1 if respondents think that more public fund should be allocated to the space projects; 0 otherwise	0.64 (0.48)
CVSAgree	=1 if respondents think that the CV scenario presented is plausible; 0 other wise	(0.53) (0.47)
Socio-demographic variable		
MInomce	Household's before tax 2008 monthly income (1,000$)	3.148 (1.401)
# of Children	Numbers of children under age 13	0.41 (0.439
Work	=1 if the respondent is working; 0 otherwise	0.78 (0.43)
HCheck	=1 if the respondent gets regular health check-up	0.37 (0.48)

<Table 3> Probit Estimates of contingent responses for environmental information

	Model 1	Model 2	Model 3
Intercept	-0.294 (-0.862)	-0.446 (-1.273)	-0.302 (-0.882)
Bids	-0.896 (-9.336)	-0.883 (-9.172)	-0.895 (-9.311)
Attitude Variable			
AQIAccuracy	-0.0047 (-1.825)	-0.00466 (-1.779)	-0.00482 (-1.850)
APHRisk	0.0604 (1.875)	0.0596 (1.835)	0.0599 (1.858)
EsInvesment	0.314 (3.387)	0.301 (3.235)	0.314 (3.390)
Socio-demographic Variable			
Mincome	0.056 (1.647)	0.0469 (1.414)	0.0564 (1.635)
# of Child	0.179 (3.047)	0.180 (3.041)	0.178 (3.016)
HCheck	0.179 (2.015)	0.143 (1.585)	0.179 (2.005)
Payment Vehicle			
PVehicle	-0.259 (2.991)	-0.220 (-1.675)	-0.234 (-2.373)
CVSAgree		0.331 (2.676)	
CVSAgree*PVehicle		-0.0299 (-0.171)	
Nwork			0.0737 (0.487)
Nwork*PVehicle			-0.113 (-0.545)
N	1,000	1,000	1,000
Psuedo R^2	0.11	0.12	0.11
Prop. of correct prediction	71.2	71.8	71.2
Mean WTP for whole sample	$3.74	$3.54	$3.70
Mean WTP for Type A	$5.48	$5.04	$5.27
Mean WTP for Type B	$2.01	$2.05	$2.13

[a] Student's-t statistics in parentheses