EASIUR User's Guide Version 0.2

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1 Introduction

The Estimating Air pollution Social Impact Using Regression (EASIUR) model (Heo 2015) predicts marginal social cost (in [$/t]) and intake fraction (in [ppm]) for air pollutants emitted anywhere in the United States and emissions from offshore (e.g. emissions from margin vessels) as well as neighboring areas in Canada and Mexico. This guide is focused on how to use marginal social costs estimated by the EASIUR model. The EASIUR's social costs are derived only on the basis of the impact of ambient $PM_{2.5}$ on mortality, which usually accounts for more than 90% of social costs. It estimates the monetized impacts of $PM_{2.5}$ from a certain emissions affecting over a large area downwind (up to about two thousand kilometers).

Currently, EASIUR predicts marginal damages of four major species: elemental carbon (EC), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and ammonia (NH_3). EC represents directly emitted $PM_{2.5}$ and, therefore, is called direct or "primary" $PM_{2.5}$. The other three species (SO_2, NO_x, and NH_3) are emitted as gas and produce $PM_{2.5}$ chemically in the atmosphere, and are called "secondary" $PM_{2.5}$. Volatile organic compounds (VOCs), which form secondary organic $PM_{2.5}$, are not modeled yet. EASIUR is derived based on ground-level area emissions and two stack-height point emissions (150 m and 300 m).

The marginal damages are derived based on the meteorology and emissions of 2005. They should be valid in the near future or past (e.g. 2005 $\pm$ 10 years), though rigorous analyses need to be done. The estimates, however, may change substantially in the longer term (e.g. 30-50 years) because large changes in SO_2, NO_x, and NH_3 emissions may change the chemical environment in the atmosphere that affects secondary $PM_{2.5}$ formation. To the contrary, the marginal damages of primary species (or EC) would not change.

2 Where to get EASIUR

EASIUR is distributed through its website: <http://barney.ce.cmu.edu/~jinhyok/easiur/>.

3 How to use EASIUR

The EASIUR model estimates marginal damages over the United States in a 148×112 grid, where one cell covers area of 36 km × 36 km. Accordingly, the marginal damage estimates from the EASIUR model are presented as two-dimensional arrays of size 148×112, where each cell points to a specific location in the U.S. domain. Sixteen arrays are provided because each species has one array per season (16 arrays = 1 array/species/season × 4 species × 4 seasons). Winter is defined as a period from January to March, spring from April to June, summer from July to September, and fall from October and December.

Three pieces of information are needed to estimate the social cost of emissions: (1) the amount (E) of emissions, (2) the location (longitude and latitude) of emissions, and (3) the season of the emissions.

An important step is to convert the location (longitude and latitude) to the EASIUR grid (or to a location (x, y) in the EASIUR's 148×112 grid). The EASIUR website provides an on-line conversion tool for a single or batch conversion.

After conversion, you will have the position of emissions (x, y) in the EASIUR grid. Then, you can find marginal emissions [$/t] from a pollutant- and season-specific EASIUR array and multiply the marginal emissions by the amount of emissions [t] to calculate the social cost of the emissions [$]. If emissions do not have season information, averages of four seasonal estimates would be used.

4 Adjusting EASIUR estimates

The EASIUR marginal damages can be adjusted for a different choice of the value of a statistical life (VSL) and a concentration-response (CR) relation. EASIUR is published with $8.8M in 2010 USD for VSL and a relative risk of 1.06 for CR.

4.1 Adjusting VSL for Inflation and Income Growth

An adjusted EASIUR marginal damage (S') for a different VSL can be calculated as follows:

$$S' = S \cdot \frac{\text{VSL}}{\$8.8M} \tag{1}$$

where S is the default EASIUR marginal damages.

Usually, U.S. EPA's official VSL will be used, which is \$4.8M in 1990 USD and 1990 income level. This VSL is the central estimate from a Weibull distribution that U.S. EPA built based on 26 value-of-life studies (U.S. EPA 2010). U.S. EPA recommends that this \$4.8M be used in benefit analyses (U.S. EPA 2010).

This \$4.8M often needs to be adjusted for a different dollar year to account for inflation. It also needs to be adjusted for income level since people are willing to pay more to avoid the mortality risk from $PM_{2.5}$ as their income grows. The U.S. EPA's official adjustment factors for these two factors are included in Table A2, which was extracted from BenMAP (U.S. EPA 2015).

For example, \$4.8M in 1990 USD can be converted to a VSL (V') in 2000 USD and 2000 income level as follows:

$$\begin{aligned} V' &= \$4.8M \cdot \frac{G_{2000}}{G_{1990}} \cdot \frac{I_{2000}}{I_{1990}} \\ &= \$4.8M \cdot \frac{1.00}{0.76} \cdot \frac{1.04}{1.0} \\ &= \$6.6M \end{aligned}$$

where G_{2000} and G_{1990} are GDP deflators and I_{2000} and I_{1990} are income level adjustment factor for year 2000 and 1990 from Table A2. Then, EASIUR's marginal damage with the default \$8.8M VSL (S') can be converted to this \$6.6M using Eq. (1):

$$S' = S \cdot \frac{\$6.6\text{M}}{\$8.8\text{M}} = 0.75 \cdot S$$

4.2 Adjusting Concentration-Response relation

The EASIUR default estimates are based on a relative risk of 1.06 for the concentration response relation, which is reported by a recent American Cancer Society cohort study (Krewski et al.

2009). The relative risk is usually defined as increased mortality per each increase of 10 $\mu g\ PM_{2.5}/m^3$.

Though the concentration-response relation is log-linear, marginal damages are almost linear to the size of relative risk over a range relevant to $PM_{2.5}$ public health effects. The base EASIUR estimates can be adjusted for a different relative risk (R) with the following factor, F_R:

$$F_R = -15.1 + 15.2R \quad (2)$$

Derivation can be found in Section 4.3.7 of Heo (2015). For example, an adjusted EASIUR estimate can be obtained for a relative risk of 1.14 from Lepeule et al. (2012), the other important $PM_{2.5}$ epidemiological study, by multiplying the following factor to the base value:

$$F_R = -15.1 + 15.2 \cdot 1.14 = 2.2$$

5 Uncertainties

Here we summarize the major uncertainties surrounding EASIUR's marginal damages.

5.1 Air Quality Modeling

Multipliers to estimate the 95th prediction intervals of EASIUR estimates are presented in Table A1 in the Appendix. If you multiply 2.5% and 97.5% factors to EASIUR marginal damages, you would get the 95% prediction intervals of the damages, which represent the uncertainty originated from air quality simulations.

5.2 Value of a Statistical Life

There is one official distribution of the value of a statistical life that U.S. EPA built based on 26 value-of-life studies (U.S. EPA 2010). It is a Weibull distribution (scale parameter $= 5.32\times10^6$, shape parameter $= 1.51$). Therefore, uncertainty analysis can be done with the Weibull distribution. The mean value of this distribution is $4.8M in 1990 dollar. The 95% confidence intervals are [$0.46M, $12.6M] in 1990 USD.

5.3 Concentration-Response Relations

Epidemiological studies of $PM_{2.5}$ on mortality publish 95% confidence intervals for the relative risk of $PM_{2.5}$. The two most important series of cohort-based $PM_{2.5}$ epidemiological studies are the American Cancer Society (ACS) study and Harvard Six Cities (H6C) study. The most recent follow-up studies as of now are Krewski et al. (2009) for ACS and Lepeule et al. (2012) for H6C. Here are the reported relative risks with 95% confidence intervals in parentheses:

- Krewski et al. (2009): 1.06 (1.04-1.08)
- Lepeule et al. (2012): 1.14 (1.07-1.22)

Uncertainties from CR relations can be explored for these confidence intervals with Eq. (2).

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Appendix

Table A1: Multipliers for EASIUR 95% prediction intervals.

	Winter		Spring		Summer		Fall	
	2.5%	97.5%	2.5%	97.5%	2.5%	97.5%	2.5%	97.5%
EC	0.61	1.64	0.67	1.49	0.67	1.49	0.60	1.68
SO_2	0.53	1.90	0.73	1.38	0.69	1.44	0.67	1.50
NO_x	0.45	2.23	0.57	1.77	0.35	2.86	0.41	2.42
NH_3	0.56	1.79	0.57	1.75	0.46	2.19	0.54	1.84

Table A2: U.S. EPA standard inflator and income growth adjustment factors (extracted from BenMAP (U.S. EPA, 2015))

Year	GDP Deflator	Income Growth Adj.
1980	0.48	-
1981	0.53	-
1982	0.56	-
1983	0.58	-
1984	0.60	-
1985	0.62	-
1986	0.64	-
1987	0.66	-
1988	0.69	-
1989	0.72	-
1990	0.76	1.00
1991	0.79	0.99
1992	0.81	1.00
1993	0.84	1.00
1994	0.86	1.01
1995	0.89	1.02
1996	0.91	1.02
1997	0.93	1.03
1998	0.95	1.04
1999	0.97	1.04
2000	1.00	1.04
2001	1.03	1.04
2002	1.04	1.05
2003	1.07	1.06
2004	1.10	1.06
2005	1.13	1.07
2006	1.17	1.07
2007	1.20	1.08
2008	1.25	1.09
2009	1.25	1.09
2010	1.27	1.10
2011	-	1.11
2012	-	1.12
2013	-	1.13
2014	-	1.14
2015	-	1.15
2016	-	1.16
2017	-	1.17
2018	-	1.18
2019	-	1.19
2020	-	1.20
2021	-	1.21
2022	-	1.22
2023	-	1.23
2024	-	1.23