Long-Run Environmental Accounting in the U.S. Economy.

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Synopsis of Paper.

The national income and product accounts (NIPAs) measure the condition of an economic system. NIPAs provide three critical perspectives both in levels and in rates of growth. First, NIPAs supply society's most widely used gauge of current conditions with an economy. Second, in a retrospective sense, NIPAs give a track record of the development of an economy. And, third, NIPAs yield the basis for economic forecasts. From all three perspectives, the NIPAs inform decisions made by policymakers, researchers, investors, and the lay public.

Environmental accounting augments the market accounts by encompassing the value of natural resources in situ and the monetary costs due to environmental damage (NAS NRC, 1999; Abraham and Mackie, 2006; Nordhaus, 2006; Muller, Mendelsohn, Nordhaus, 2011). Environmental accounts, like their market counterparts, are motivated by the need to measure the condition of an economic system and their value manifests in relative, retrospective, and prospective terms. Prior papers is this field report environmental damage in a retrospective manner for particular data years (Bartlemus, 2008; Muller, Mendelsohn, Nordhaus, 2011). Other published work examines

environmental accounts over short time series (Muller, 2013a; Muller, 2014). Historical data is used herein to develop a 75-year series of Gross External Damage (GED), (Muller, Mendelsohn, and Nordhaus, 2011; Muller, 2014), a macro environmental indicator encompassing air pollution emissions from all sectors in the United States (U.S.) economy. This aspect or dimension of environmental accounting is chosen because of (1) data availability and (2) the potential for inclusion of air pollution damage into the accounts to appreciably affect estimates of comprehensive consumption (NAS NRC, 1999; Muller, 2013a). This is the first paper that provides estimates of long run environmental accounts.

This paper will produce GED estimate for the U.S. economy from 1940 through 2014. The paper will use an integrated assessment model (IAM) to estimate damages, both on a per ton basis, and in total GED for the years 1999, 2002, 2005, 2008, 2011, and 2014[1]. The IAM used to estimate GED is the AP3 model, an update to the APEEP family of models (Muller and Mendelsohn, 2007; 2009; NAS NRC, 2010; Muller, Mendelsohn, Nordhaus, 2011; Muller; 2013a; 2013b; 2014; Clay et al., 2018). Pollutants covered include particulate matter ($PM_{2.5}$), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and volatile organic compounds (VOC). To construct the historical series, the paper will use emission estimates provided by the USEPA (2000). These are shown in figure 1. These data are national totals.

[1] These years are selected due to the availability of the USEPA's national emissions inventories.

In order to estimate historic GED from these emissions data several steps are necessary. First, the analysis must project marginal damages back from 1999 to 1940. Two methods are used to extrapolate the historical marginal damage series. The first posits that changes in marginal damages are proportional to income levels. Prior research has shown that air pollution damage is primarily composed of premature mortality risk (USEPA, 1999; Muller and Mendelsohn, 2007; Muller, Mendelsohn, Nordhaus, 2011), and that the willingness-to-pay (WTP) to avoid mortality risk is driven by the income level of the population at risk (Costa, Kahn, 2004; Hammitt, Robinson, 2011). Using this approach, the USBEA's real personal income series is used in conjunction with WTP-income elasticities reported in the literature (Costa, Kahn, 2004; Hammitt, Robinson, 2011) to estimate nominal marginal damages back from 1999 to 1940. The second method empirically estimates the relationship between population, emission levels, and marginal damages from 1999, 2002, 2005, 2008, 2011, and 2014 using regression analysis. Together with historical population and emissions data, the fitted parameter estimates are then used to calculate marginal damages back to 1940. Preliminary estimates of these marginal damages are shown in figure 2.

With marginal damages and emissions over the period 1940 – 2014, GED is computed, in keeping with national accounting principles, by multiplying the marginal damage times emissions. (See NAS NRC, 1999 and Abraham and Mackie, 2006 for a discussion of this approach.) This procedure yields an imputed GED series over approximately 75 years. Figure 3 displays preliminary estimates of the national GED series.

More formally, the nominal GED are computed by multiplying the emissions (E) of pollutant (s), at time (t), denoted ($E_{s,t}$) by the corresponding marginal damage of emissions, $MD_{s,t}$. The methods used in the empirical estimation of the $MD_{s,t}$ are described and explored in past applications (Muller and Mendelsohn, 2007; 2009; Muller, Mendelsohn, Nordhaus, 2011; Muller, 2014). Note that in the current paper, the historical emission series does not contain information on source type or location. As such, national average marginal damage values for each pollutant are used. The marginal damage is matched by pollutant (s) and time period(t) to the corresponding emissions level ($E_{s,t}$).

$$GED_{s,t} = E_{s,t} \times MD_{s,t} \tag{1}$$

To compute nominal GED for the entire economy, across pollutants, equation (1) is aggregated by summing across all pollutants.

$$GED_t = \sum_{s=1}^{S} \left(E_{s,t} \times MD_{s,t} \right) \tag{2}$$

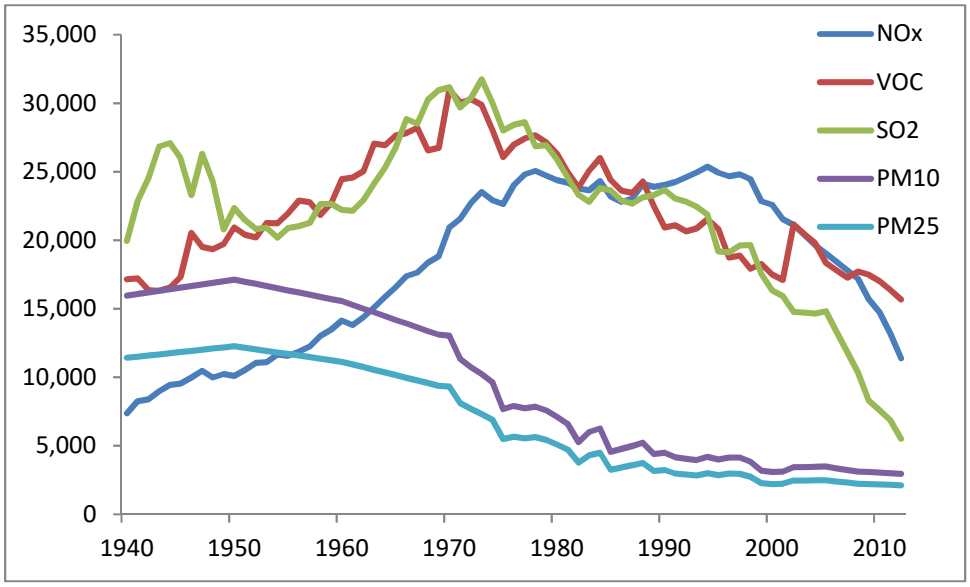
The analysis relies on real VA reported by the U.S. Bureau of Economic Analysis (BEA), (USBEA, 2011). A critical gauge as to the magnitude of the GED is the GED-to-VA ratio. In order to compute the GED/VA ratio for 1940 forward, historical, real annual VA for the total economy provided by the USBEA is employed. The GED is then computed as in (1) and (2), and the ratio of GED-to-VA for each year from 1940 to 2014 is computed.

In keeping with the environmental accounting literature, the present paper deducts the GED from economy-wide VA to compute an adjusted measure of national output: EVA (Muller, 2014). The paper will tabulate annual growth in real EVA and compare this to growth in economy-wide VA. Based on the findings in Muller (2014), significant differences in the EVA and VA growth rates are anticipated throughout the 20th century. A critical determinant of the relative rates of growth in EVA and market VA is whether emissions and damages are rising or falling. Based on figure 1, this paper may yield especially interesting results in light of the widespread implementation of environmental policies in the 1970s.

For the years 1970 through 2014 the paper will produce sector-specific GED. These sectors correspond to categories for which the USEPA reports emissions totals over this time horizon: electric utilities, other industrial fuel combustion, chemical manufacturing, metals manufacturing, petroleum refining, solvent use, waste disposal, and transportation. Economic data by sector will be used to gauge the magnitude of GED for each sector by comparing to sectoral VA. Growth rates in market VA and EVA (VA – GED) by sector will also be computed. This set of exercises will thus track changes in the composition of the economy and corresponding pollution damage.

Figures

Figure 1. Historical Emissions.



Vertical axis 1,000 short tons.

Source: USEPA, 2000.

Figure 2: Nominal Historical Marginal Damages ($ current).

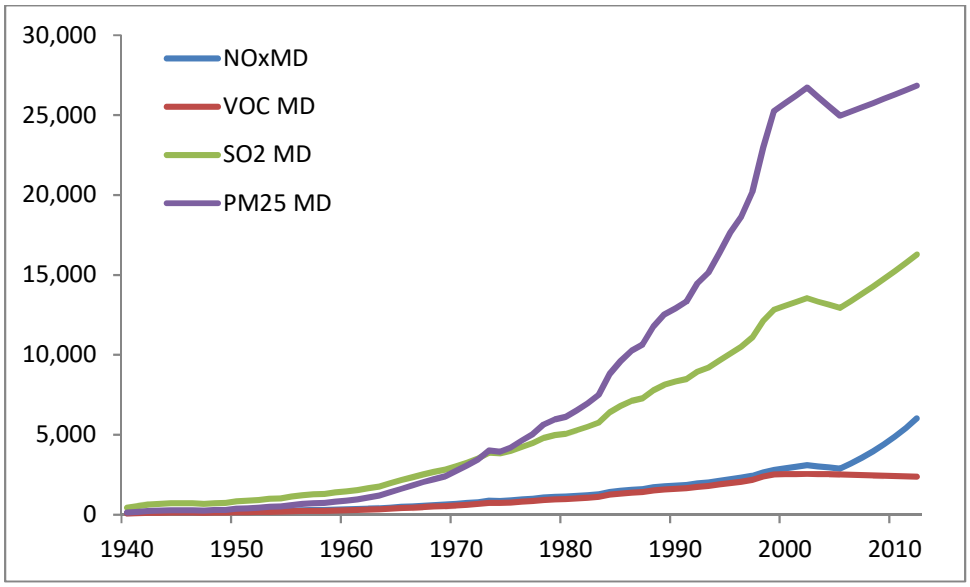
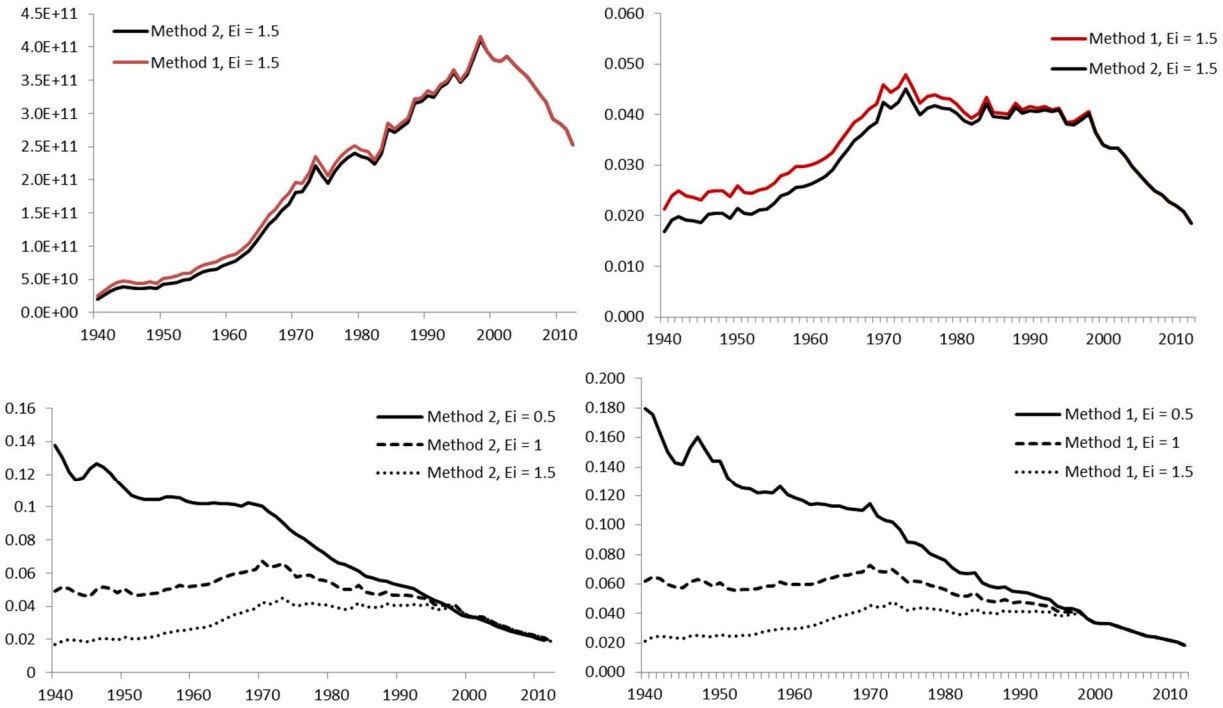


Figure 2 employs damage extrapolation method 2 and an income elasticity for VSL of 1.5.

Source: Author's Calculations.

Figure 3: Historical GED and GED/GDP Series.



Source: Author's Calculations.

Top left panel: vertical axis GED ($). Top right panel: vertical axis GED/VA. Bottom right panel: vertical axis GED/VA. Bottom left panel: vertical axis GED/VA.

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