Isolating critical uncertainties: emission projections built on drivers

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Technology Based Model

- Emissions vary with introduction of advanced technology and implementation of stringent environmental regulations. (Bond et al. [2004], Streets et al. [2004], Rao et al. [2005])
- Feasibility: Technology based model has been built to project future emissions under different economic scenarios
- Exhaust emissions from on-road vehicles are studied

What are the limitation of our knowledge about these projections?
Uncertainty analysis

- Current projection models are deterministic
  - Single answer for each scenario
  - Do not account for uncertainties in policy and technology dynamics
  - Relationship between technological change and economic conditions is not perfectly known

- Value of uncertainty analysis
  - Identify most critical areas of uncertainty
  - Provide suggestions on technology change and environmental policy considering this uncertainty
Sources of Uncertainty

- Economic and social development*
  - Fuel consumption growth rate
  - GDP change
- Retirement rates@
  - Depend on income and vehicle age
- Superemitter @
  - Poorly tuned or defective vehicles
  - Depends on age and lifetime
- Emission standards@
  - Timing linked with GDP
Economic Development

- This is the major source of uncertainty
  - Economic growth (e.g., GDP or GDP/cap)
  - Energy growth (e.g., fuel consumption)

- IPCC Special Report on Emission Scenarios (SRES)
  - Main driving forces of future emissions and economic developments
  - A1B, A2, B1 and B2

http://www.grida.no
Global PM emissions will **increase** from the 2010 value of 900-960 Gg to 1000-1300 Gg in 2030 and 1000 to 2000 Gg in 2050.

The uncertainty among economic scenarios is **about a factor of two**.
Regional Details

- All regions increase continually in A1B
- Emissions increase in the developing world
- South Asia has the largest annual average increase
Emission composition by engine type

- Emission projections highly dependent on the behavior of “superemitters.”
- More than 50% produced around 2010
- 10% population → 80% emission

- In 2050, total emissions reduce 75% without superemitters
- Decreases rate is 2-4% per year.

- Tighter standards cannot satisfactorily protect environmental quality unless superemitters are addressed specifically
- Global emission trends will remain highly uncertain until the behavior of superemitters is better understood
Global Emissions

- Decreasing emission intensity: **PM increases more slowly than fuel consumption**
- **In A2, cheap labor** might make clean technology **less expensive**, so people can afford new cars, **emissions are less**.
Economic Model

Energy Conditions

Vintage

Fuel by tech

Retire

Economic Conditions

Age

Alter

Superemitter

Activity

Hazard

Speciated Pollutant Emission Wizard (SPEW)-Trend

Future Emission

Emission Standard

Emission Factor
Retirement (Scrappage) Rate

- **Definition:** the final scrapping or retiring of equipment so that it no longer contributes to the emissions or fuel consumption of the fleet

\[ R(t, \Delta t) = 1 - \frac{Su(t + \Delta t)}{Su(t)} \quad \text{Survival rate} \]

- **Governing Factors**
  - vehicle age
  - ratio of regional and global income (labor vs. price) \( \rightarrow \) `loc_glob_gdprat`
    - when the cost of repairs is high relative to the price of new cars
    - Assumption: Prices of new vehicles \( \rightarrow \) set by the global market; repair costs \( \rightarrow \) local labor rates

- **Function:** logistic

\[
Su = \frac{1}{1 + \exp\left\{ -\left[ \alpha + age \times (\beta_1 + \beta_2 \times loc\_glob\_gdprat) \right] \right\}}
\]

- \( \alpha \): related to the onset of significant retirement
- \( \beta_1 \): how quickly vehicles retire as they get older
- \( \beta_2 \): scrappage decision based on the balance of vehicle cost and repair (income level)

- **Observation Data (Iterative procedure)**
  - total vehicles registered or in use for different years
  - vehicle age distribution at a specific point in time
  - Only loosely constrained by observations
  - Observational data are limited on global scale
  - Uncertainties arise from the iterative procedure and the derived relationships between retirement rate and income
Uncertainty: Retirement Rate

- Changed within 95% confidence intervals, global emissions vary from -31.9% to +59.0%

- $\beta_1$ is the most sensitive parameter in the retirement rate function
Superemitters

- A small change in the number of superemitters will cause big changes in total emissions ([Hansen and Rosen [1990], Lawson et al. [1993], and Zhang et al. [1995]])
- A modified logistic function to represent the rate of superemitter transition

\[ af = \frac{gain}{1 + \exp\left(\text{shape} \left(\frac{\text{age}}{\text{life}} - 1\right)\right)} \]

- Maximum rate
- Rate at which normal vehicles become superemitters (fraction per year)
- Slope of this curve with age
- Vehicle life at which the rate becomes half the maximum

- 5% for the U.S. and Europe; 10% for Eastern Europe; and 20% for Asia and Latin America

- This is an empirical model
- The boundary between super- and normal emitters is not always clear
- Few observations or statistical data
Uncertainty from Superemitter Transition

- In the sensitivity studies, the median life parameter \((\text{life})\) in the superemitter transition rate is changed ±50%, resulting in emission changes of ±13%.

- The fraction of fuel consumption from superemitters varies from 10.3% to 16.7% (13.7% in baseline), while the fraction of emissions varies from 83.3% to 89.7% (87.4% in baseline) in 2030.
Conclusion

- The global emission projection shows increasing trend in all scenarios during 2010-2050, but the regional emission trends are diverse.

- **Superemitters drive the trend of PM emissions from on-road vehicles.**
  - If superemitters are eliminated, the global emission decline instead, with an annual average rate of 2%-4% per year.
  - Tighter standards cannot satisfactorily protect environmental quality unless superemitters are addressed specifically
  - Global emission trends will remain highly uncertain until the behavior of superemitters is better understood

- While future economic trajectories (IPCC scenarios) lead to the greatest uncertainty, lack of knowledge about retirement rates and the contributions of superemitters results in an additional uncertainty in total emissions
Thank you😊 Questions?