Understanding Historical Emission Trends

Josh Warren
Undergraduate Program in Statistics
North Carolina State University

Faculty Mentor
William F. Hunt, Jr.
Visiting Senior Scientist

Client:
Dr. Linda Chappell
U. S. Environmental Protection Agency

Abstract:

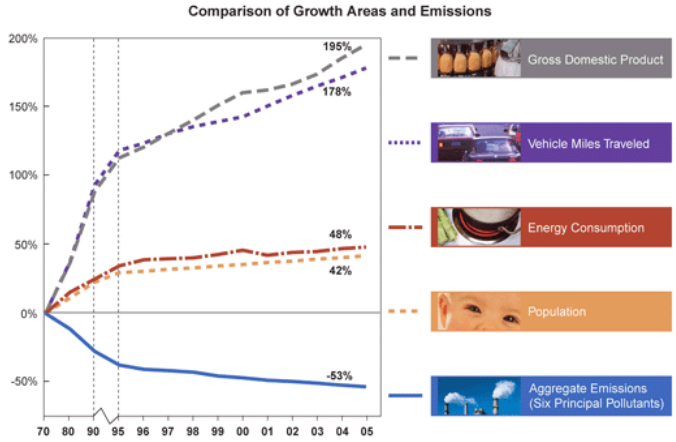
Air pollution is harmful to people and the environment. In order to better understand the nature of the environmental problem, emission inventories are developed for all sources in an area. They are based upon engineering estimates. They represent both gases and particles of air pollution that are emitted into the air by a variety of sources. Emission inventories (E/I) change over time and may be reduced as result of emission control programs. The U. S. Environmental Protection Agency's (USEPA) Office of Air Quality Planning and Standards (OAQPS) is responsible for the National Emissions Inventory (NEI). Emissions data are collected by state, local, tribal and the federal governments. The E/I includes a number of different sources: (1) Point sources – stationary locations of pollution include factories, pulp and paper mills, petroleum refineries, electric power plants, etc.; (2) Mobile Sources - cars and trucks, airplanes, etc.; (3) Biogenic sources – natural sources of emissions – trees, animals, etc.; (4) Area Sources – small stationary source of emission such as dry cleaners and degreasing operations.

Future emissions are critically important when trying to determine the impact of air quality standard regulations that are protective of human health and the environment. How will regulations impact sources in the future making changes needed to reduce emissions to achieve the air quality standards? Emissions inventories are projected for future years to conduct analyses for EPA rulemakings. The methods for forecasting emissions into the future are complex. The objective of this project is to improve upon the existing method to forecast future emissions. Two sectors will be examined to forecast future emissions – petroleum refineries and chemical manufacturing. The pollutant that will be examined is nitrogen oxides. An effort will be made to take technological change into account using gross domestic product and other variables. The Presidents Energy Plan to reduce oil consumption by 20 percent in 10 years will be used to forecast future emissions. Different alternatives will be examined in the paper.

1. Background:

Many methods have been used to estimate emission trends for future years. The Economic Growth and Analysis System (EGAS) is used to help estimate growth or decrease in emissions based on projected economic activity changes. The EGAS has been found to be problematic when forecasting for stationary non- Electric Generating Unit (EGU) sources. The future projections are inconsistent with the historical data. The current approach used to forecast emission trends begins with a base year and grows according to growth in the GDP. Compared with historical data, it overestimates future emissions by not taking future technological change and other causal factors into account into account.

Figure 1:
Graphical Description of Background and Underlying Problem:



Source: http://www.epa.gov/airtrends/

2. Methods and Results:

Phase 1 Analysis:

Initially, an investigation was undertaken to determine the relationship between real dollar GDP and NOx emissions. In order to do this, scatter plots and correlation matrices were created between the real GDP and total NOx emissions, emissions from the chemical manufacturing sector, and from the petroleum refineries sector. Through this analysis, it can be seen that as the GDP increased over time, the NOx emissions for these two sectors and for overall NOx emissions decreased. This result was counterintuitive but with very high correlation coefficients for the two sectors and overall emissions, it appears that the real GDP would be a successful predictor of NOx emissions. One plausible rationale for the negative relationship between GDP and emissions may be that over time technological innovation has allowed increased production with less NOx emissions. Once a worthy predictor was discovered, this theory was tested and I moved on to phase 2 of the analysis.

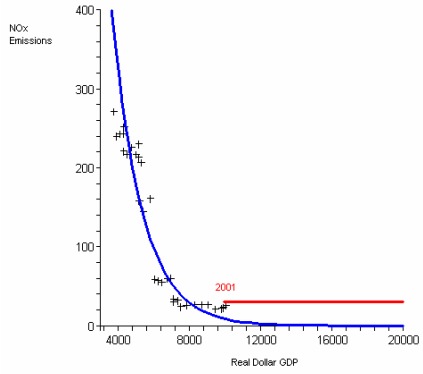
Figure 2:
Correlation Coefficients:

	Total NOx Emissions	Chemical Manufacturing	Petroleum Refineries
Real GDP	**-0.91654**	**-0.89768**	**-0.67395**

Phase 2 Analyses:

Next the focus was focus solely on the chemical manufacturing sector. A regression model was created based upon the data available from 1970 till 1990. The model was then extended through the year 2002. This was done to see how well the model, based upon the real GDP, would be able to predict the emissions for the years after 1990 for which data points already existed. Another model was created based upon the idea that emissions will remain constant when applied to a base year which was chosen to be 2001 based upon the EPA's methods. This is the proposed EPA interim approach. Both of these models were then compared to see which was the most accurate at predicting emissions through the year 2002 and to see what the emissions may look like in the future for the chemical manufacturing sector.

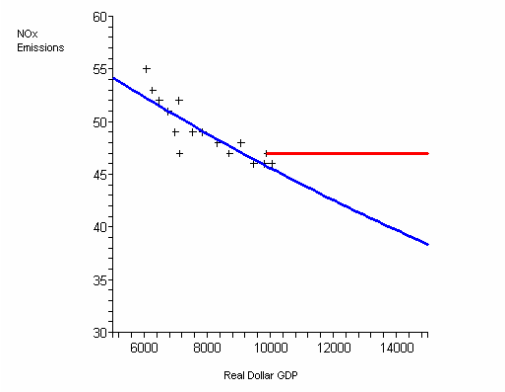
Figure 3:
Comparison of both Models:



Blue= regression model
Red= Proposed EPA interim Approach

Next the focus was on the petroleum refineries sector. The same steps that were used for the chemical manufacturing sector were applied to the petroleum sector. There were some slight differences in the results though. In creating a regression model using all the available data, a discrepancy was identified in the data. From 1971 through 1984 we saw that the data was following a different model than the data from 1985 through 2002. Around 1986 lead was almost completely removed from the gasoline and that this was possibly the reason for the differences in the two periods identified in the data (1971-1985 and 1986 on). This meant that creating a single

regression model for all of the data made no sense. Instead, the focus of this analysis is on data from 1985 until 2002. The regression model was created based upon the 1985 forward data and once again it was compared with the proposed EPA "interim" approach applied to the base year of 2001. This gave us some idea of what emissions may look like in the near future.

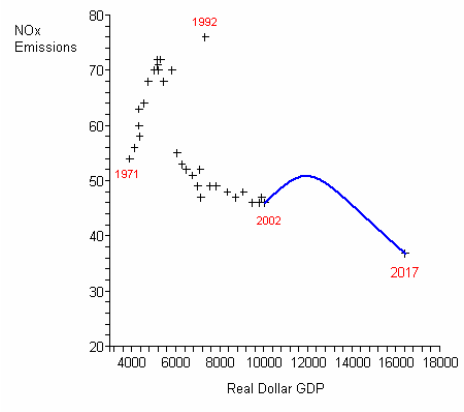


Blue= regression model
Red= Proposed EPA interim Approach

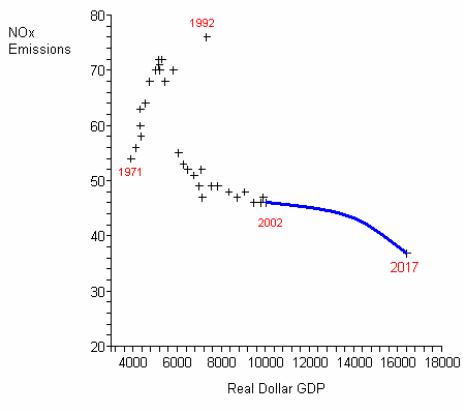
Phase 3 Analysis:

For the next part of the analysis the focus was on the petroleum refineries sector. The plan was to create two possible models based upon the President's Energy Plan which sets a goal of a 20% reduction in oil consumption by 2017. Our main assumption is that a 20 % reduction in oil consumption will lead to a 20% reduction in NOx emissions for the petroleum refineries sector. Based on this assumption, two models were created which depicted this reduction in emissions by 2017. The first model assumes growth in the short run until a gradual reduction by 2017. The second model assumes no growth in the short run, only a steady decline by 2017.

Additional assumptions were used for this analysis. It was assumed that no new refineries would be built in the United States. In the short term any gas increase was assumed to come from overseas (i.e.: India, Europe, etc.). Another assumption was that cars would become more fuel efficient and that ethanol, bio-diesel, diesel and hybrids are used more frequently.



Model 1



Model 2

3. Conclusions and Recommendations:

Through the analysis done in this project, it appears that growth in the Real GDP is a good predictor of future NOx emissions within the stationary non EGU sectors. While this predictor may be counterintuitive, the increase in the Real GDP appears to signify technological innovation and ultimately a decrease in NOx emissions. Although a crude estimator, the Real GDP seems to take into account technological change indirectly.

After looking over our results, a pattern in the data is apparent within the stationary non EGU sectors. From 1970 to about 1990 the data appears to follow one model and then from 1990 till the present, the data appears to suggest the model has changed as emissions begin to flat-line. I would like to investigate what the cause of this change is within the chemical manufacturing and petroleum refineries sectors. I also plan on adding an additional non EGU sector and see if this trend continues. Through these analyses, I hope to investigate the effect of the Clean Air Act (CAA) Emission Controls on NOx emissions in all three of the sectors.