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The Real State of CO2 Emissions; An Update to Lomborg and Analysis of Current and Future CO2 Emissions

Introduction

In 2000, Bjorn Lomborg, an Associate Professor of Statistics at the University of Aarhaus in Denmark, made an effort to collect in-depth statistical analysis of various enviornmental issues along with various interpretations and conclusions and compiled it into a best selling book titled "The Skeptical Environmentalist: Measuring the Real State of the World[6]. Among one of the issues touched in the book was the future of CO2 (and other Fossil Fuel) emissions in the context of global warming.

The data is a measurement of CO2 concentrations taken over a period of almost 50 years at various marine measurements sites over the world owned by the Earth System Research Laboratory (ESRL, part of the U.S Department of Commerce). For each site data was collected over the decades on CO2 concentration (in parts per million) and time the measurement is taken. The CO2 amount is measured as a dry mole fraction, or the ratio of CO2 molecules in the air sample to all molecules (after removal of water vapor). According to the ESRL, their methodology is as follows: “A global average is constructed by first fitting a smoothed curve as a function of time to each site, and then the smoothed value for each site is plotted as a function of latitude for 48 equal time steps per year. A global average is calculated from the latitude plot at each time step”. The finished data set has two columns, one for a time variable with relevant year and one for a continuous-valued carbon dioxide growth rate (in ppm) . PPM is a measure of how many particles CO2 are present in a sample of one million air particles, so a ratio of 0.000402 is listed as 402 ppm. This paper will attempt to update the data used in the book (ranging from 1949 - 2000) into the modern day (2015) and examine whether the trends and conclusions identified by Lomborg still ring true. Between popular scientists and many news outlets the issue of global warming has become quite well-known to the general public, and while there is little doubt that global climate trends are shifting[1] the state of the current situation (compared with history) and future predictions are an area of hot debate . About two in three Americans (71%) believe global warming is happening[2] and this is generally supported by climate data. This data is particularly important at the moment because of the rapidly increasing rate of technology advancement [2], to get a better grip on whether such advancement is adverse for the environment.

Original Data

The source of the original data used by Lomborg (pg. 279) is a combination of the same data cited above (CO2 measurements by ESRL) combined with analysis done by the Intergovernmental Panel on Climate Change (IPCC) and conclusions drawn with a paper released by Hansen and Soto in 2000. The data covers a time period from 1851 to 1998 and is available as global data. Lomborg merged the data with measurements of other gases (CFC’s, Nitrous Oxide, and Methane) and scaled the measurements to be in terms of CO2 equivalents (to account for the addition of other gases).

Original Data Interpretation

Lomborg thinks the data is important as other explanations of climate change such as the sunspot cycle are not adequate to explain all variance in global temperature, and there is a confirmed link between greenhouse gas emissions and weather changes. For Lomborg, the graph constructed from the data is used to display the progression of Greenhouse Gas emissions throughout the the last five decades and lay a foundation for presenting IPCC predictions on future emissions in the following few pages. Arguably, the data does serve its purpose in providing a snapshot of how greenhouse gas emission trends have been but does not, by itself, present a good baseline for extrapolation, as noted by Lomborg and the IPCC in their projections. Since forecasting is better done with data on a process that is largely self-contained and growth or reduction is due to inherent patterns in the consumption or evolution of the system underlying the data, the IPCC has included other data in its projections of future emissions. The IPCC projections have been “set to fit two quantitative targets, population and wealth”. These serve as good proxy variables for many factors that may affect emissions, like industrialization, alternate fuel usage and . There is a trend of increasing emissions in the original data, with large jumps every decade after 1960. This trend may be explained by increases in general industrialization and population of the world.

New Data

The data used in this paper is simply an update of data used by Lomborg and thus uses the same collection methods and reporting methodologies outlined under the introduction. The update spans a time period of 16 years from where Lomborg leaves off (1998) to the latest available year (2014). Updates span the same regions as original and are reported as global data. In general, the data shows an increasing trend despite their being numerous technological advancements over the period [4]. There is more countries then ever achieving industrialization also, and this may counter the effects of individual countries becoming more environmentally friendly. [5]

The following charts are provided to summarize the findings and provide a general overview of trends described. We provide 3 graphical aids.

(1): Mean Global Temperature and CO2 Emissions carry a 0.78 correlation (out of 1, a perfect correlation). This is indicative of there being a strong (not necessarily causal) relationship between these two things, this chart helps show the general increasing trend in both of these variables throughout the last several decades.

(2) CO2 Emissions by Year in PPM: This provides a closer snapshot of the second series in chart 1, showing CO2 Emissions by Year for the last several decades. This chart helps provide a glimpse into the overall variability of CO2 emissions and provides a framework for understanding CO2 Emission changes in accordance with global events that may have occurred during a certain time frame.

(3) A collection of significant global metrics and their correlation with the global mean temperature, CO2 emissions and cross-correlations. This is provided for exploratory purposes only and to guide possible future predictive analysis techniques. All data gathered from the World Bank.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | A | B | C | D | E | F | G | H | I |
| A | 1.00 |  |  |  |  |  |  |  |  |
| B | 0.80 | 1.00 |  |  |  |  |  |  |  |
| C | 0.78 | 0.53 | 1.00 |  |  |  |  |  |  |
| D | -0.19 | 0.00 | -0.34 | 1.00 |  |  |  |  |  |
| E | 0.79 | 1.00 | 0.53 | 0.00 | 1.00 |  |  |  |  |
| F | 0.77 | 0.98 | 0.46 | 0.07 | 0.98 | 1.00 |  |  |  |
| G | -0.67 | -0.85 | -0.32 | -0.22 | -0.85 | -0.90 | 1.00 |  |  |
| H | 0.76 | 0.97 | 0.44 | 0.10 | 0.97 | 1.00 | -0.91 | 1.00 |  |
| I | -0.06 | 0.11 | 0.28 | -0.36 | 0.11 | 0.05 | -0.05 | 0.02 | 1.00 |
| J | -0.17 | -0.24 | 0.17 | -0.40 | -0.23 | -0.39 | 0.54 | -0.45 | 0.24 |
| **Annual Mean Temp (F)** | **A** |  |  |  |  |  |  |  |  |
| **Year** | **B** |  |  |  |  |  |  |  |  |
| **CO2 Emissions (ppm)** | **C** |  |  |  |  |  |  |  |  |
| **Recession?** | **D** |  |  |  |  |  |  |  |  |
| **World Population** | **E** |  |  |  |  |  |  |  |  |
| **GWP** | **F** |  |  |  |  |  |  |  |  |
| **Income Share Held by Top 10%** | **G** |  |  |  |  |  |  |  |  |
| **Electricity Usage (KwH)** | **H** |  |  |  |  |  |  |  |  |
| **Forest Area (km)** | **I** |  |  |  |  |  |  |  |  |
| **Alternative Energy (% of total)** | **J** |  |  |  |  |  |  |  |  |

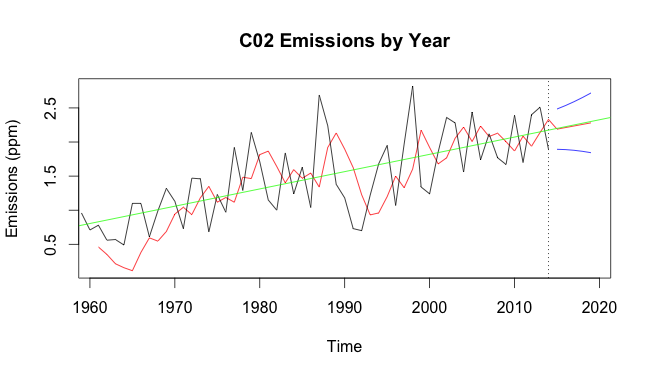
Correlations of C02 Emissions and Global Mean Temperature with Major World Metrics. Chart 3

New Data Interpretation

The updated data shows the continuation of such a trend with a general linear increase in CO2 emissions with seasonal fluctuations. This trend is very consistant with the trend apparent for the time period reported by Lomborg. While there are multiple factors that contribute to CO2 emissions, the two main ones explored by the IPCC in regards to the emissions data, world population and global wealth, have had trends that have stayed reletively similar over the period reported by Lomborg and the updated period. We provide brief projections to 2030 using additional data that has become available only recently and compare these with projected scenarios from the IPCC for emissions.

Conclusion

Lomborg was correct in his statements regarding that many of the IPCC models "run away too fast" with increases in emissions and have "unrealistic assumptions" with regards to a stagnation of technological advancement. The trend seen in the updated data is largely consistant with the previous several decades with no strong swings in either direction. Lomborg also examines IPCC scenerios and reports that with the most "realistic development for solar power, the tempreture will only 0.7C for the next 50 years". Using the latest tempreture data with a simple time series model predicts that Lomborg is suspected to be largely correct in this area as well. We provide a simple time series forecast using Holt-Winters smoothing (red) and a linear model using an intercept and time as a predictor for CO2 Emissions (green). Both of these models predict a steady rise in CO2 Emissions. For more complex models the factors in chart (3) should be evaluated and placed into context. Policy curbing CO2 emissions may be explained by the shrinking variance seen in yearly emissions, suggesting major developed producers of CO2 (US, European Union) are experiencing a lower amount of runaway pollution, while the general linear trend may be explained by countries with rapidly growing economies (India, China) whom have not yet reached the tipping point in terms of wealth for beginning to lower emissions [4]. Based on such observations, a good step forward in developed countries would be establishing guidelines for predicted CO2 emission for companies and requiring companies to publicly report excess CO2 produced along with documentation on the reasons. Thus, consumers with a strong preference for environmental quality will stop purchasing from such companies and provide an incentive to equalize green standards of their competitors. Along with established standards in place by governing environmental bodies (such as the EPA) we should see a further reduction in the variance of emissions by developed countries. For developing countries we may provide guidelines of “reasonable reduction” in CO2 emissions by introducing pollution permits at a lower cost, thus providing an incentive for companies to not over-emit while still allowing necessary pollution (by developing country standards) to be affordable.



Citations/Sources:

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