A Ratio for the Relative Climate Change Impact of an Economic Activity

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Abstract
I propose a ratio for assessing the climate change impact of an economic activity as a function of global greenhouse gas emissions and annual gross world product. To construct a simple example, I consider only CO_2 emissions and use the purchase and combustion of gasoline. I show that it has a ratio of 8.82:1 in the United States as of March 6, 2019 at a national average price of $2.44 per gallon. This means that in consideration of the direct impacts of gasoline's combustion alone, gasoline would have to cost $21.50 per gallon in order to achieve a 1:1 ratio. Other applications of the ratio and its impact are discussed.

Keywords: climate change, co2, greenhouse gas emissions, economics, fossil fuels, relative harm, carbon taxes

Herein I propose a ratio for the relative climate change impact of an economic activity. The ratio can be calculated with respect to a particular product, activity, industry, sector, country, or other unit (referred to as "activity" herein). To calculate the ratio, we must first ask: If all the economic activity in the world consisted solely of this activity, how much of this activity in economic terms would result in the same amount of greenhouse gas (GHG) emissions that are presently occurring worldwide? If we, for simplicity, are only looking at carbon dioxide (CO_2) emissions, we can substitute CO_2 for GHG.

Armed with the preceding dollar figure, we must construct a fraction (Figure 1) with annual gross world product (GWP)[1] as the numerator and the prior figure as the denominator—that is, economic output for the activity in question at parity with emissions for the year.

$$\frac{\text{Gross world product (GWP)}}{\begin{array}{c}\text{Extrapolated GWP if activity in question was conducted singly at massive scale}\\ \text{producing emissions equivalent to worldwide emissions for the year in question}\end{array}}$$

Figure 1. Equation for ratio of GWP to an economic activity in terms of GHG emissions.

This ratio came to mind when I was considering the low cost of gasoline in Florida and the United States in general. I noted that if you could buy astronomical quantities of gasoline at the prices offered, you would have enough to produce more than *worldwide* CO_2 emissions long before reaching the United States' gross national product (approximately $21 trillion) *alone*.

[1] GWP is an economic abbreviation, not to be confused with global warming potential which is a ratio referring to the warming potency of a greenhouse gas over a given timeframe. For example, methane has a global warming potential of 28–36 over 100 years, meaning it is 28 to 36 times as impactful by volume as compared to CO_2; however, methane's global warming potential is much higher in the short term.

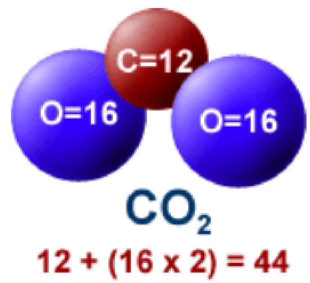
In 2018, worldwide CO_2 emissions were 37.1 billion metric tons (“tonnes”), and GWP was, by the International Monetary Fund’s estimate, $88 trillion U.S. dollars. Figure 2 shows a screenshot from a U.S. government webpage explaining how a gallon of gasoline results in 20 pounds of CO_2 emissions when combusted. As a measure of total impact of motoring, this is in fact conservative (other emissions result from oil refining, transportation, construction and maintenance of automobiles and roads, etc.), but I will use it here for simplicity.

How can a gallon of gasoline produce 20 pounds of carbon dioxide?

It seems impossible that a gallon of gasoline, which weighs about 6.3 pounds, could produce 20 pounds of carbon dioxide (CO2) when burned. However, most of the weight of the CO2 doesn't come from the gasoline itself, but the oxygen in the air.

When gasoline burns, the carbon and hydrogen separate. The hydrogen combines with oxygen to form water (H2O), and carbon combines with oxygen to form carbon dioxide (CO2).

A carbon atom has a weight of 12, and each oxygen atom has a weight of 16, giving each single molecule of CO2 an atomic weight of 44 (12 from carbon and 32 from oxygen).



Therefore, to calculate the amount of CO2 produced from a gallon of gasoline, the weight of the carbon in the gasoline is multiplied by 44/12 or 3.7.

Since gasoline is about 87% carbon and 13% hydrogen by weight, the carbon in a gallon of gasoline weighs 5.5 pounds (6.3 lbs. x .87).

We can then multiply the weight of the carbon (5.5 pounds) by 3.7, which equals 20 pounds of CO2!

Figure 2. CO_2 emissions of gasoline. Source: FuelEconomy.gov.

The American Automobile Association estimates that the average U.S. gas price as of March 6, 2019 is $2.44 per gallon. A tonne is 2,205 pounds, so one must combust 110.25 gallons of gasoline to emit one tonne of CO_2, which would cost $269.01 at $2.44 per gallon. Multiplied by 37.1 billion tonnes (the amount of worldwide CO_2 emissions in 2018), this gives us a cost of $9,980.27 billion, or $9.98 trillion, for our fraction’s denominator (Figure 1). Our numerator, 2018 GWP, was $88 trillion, which dividing by $9.98 trillion gives a ratio of 8.82:1.

A ratio of 8.82:1 means that the purchase and combustion of gasoline has a disproportionately high impact on CO_2 emissions as compared with its impact on GWP. In order to make the ratio 1:1, we would have to multiply gasoline’s price by 8.82 yielding a price of approximately $21.50 per gallon! Although transportation facilitates many economic activities that, in economic value, exceed its purchase price alone, this is nonetheless a surprising figure.

Behavior of the Ratio

At a 1:1 ratio where the numerator and denominator are equal (Figure 1), an activity's emissions are in proportion with its economic value at a global scale. Higher ratios, such as gasoline's ratio at 8.82:1, indicate that emissions exceed an activity's economic value. Lower ratios would indicate that an activity is emitting less in proportion to its economic value at a global scale. For instance, a ratio of 0.5:1 would indicate that if an activity was extrapolated to emit 37.1 billion tonnes of CO_2 in 2018 at linear economic value, it would be worth $176 trillion—that is, double 2018's GWP of $88 trillion.

The ratio is not useful for economic activity that removes CO_2 from the air ("net-negative" economic activity), although a negative ratio for such scenarios could be conceived. Additionally, a similar ratio for the relative value of carbon-negative activities that cost money could be constructed.

Other Uses

One can construct a similar ratio for other types of ecological damage. For instance, one could look at use of fresh water in economic terms. If we were to look at fracking, for instance, we would find that it uses tremendous amounts of fresh water relative to its economic output, so the ratio would be quite high.

A more complex analysis might weight an activity on overall impact rather than emissions alone. For instance, activities that remove trees should be measured based not only on emissions but also on the fact that they are removing a carbon sink from the earth. Air travel should be measured not on GHG emissions alone, but also adjusted with a multiplier because emissions are more deleterious at high altitudes.

The ratio can be used at the national level, although such comparisons should be adjusted for human and economic development, perhaps using measures such as the human development index. The United States emitted about 5.32 billion tonnes of CO_2 in 2018 (14.3% of worldwide total of 37.1 billion tonnes) but was responsible for $21 trillion of GWP (23.9% of worldwide total of $88 trillion), which suggests a ratio of about 0.6:1, although this is an unfair comparison to other nations.

Impact

The ratio is an interesting way to think about climate impact of an economic activity, especially if humanity moves toward decarbonization to ameliorate ongoing and impending calamities from past and present GHG emissions. It could be used by policymakers toward carbon taxes, cap-and-trade schemes, or other initiatives, and may have broad appeal to both researchers and the general public.