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Analyzing CO2 Emissions in Bangladesh using the IPAT Model

The relationship between human activity and environmental change has continued to be a central question in studies regarding sustainability. One of the most widely used tools to capture this relationship is the IPAT model, an equation that represents environmental impact (I) as the product of population (P), affluence (A), and technology (T). According to the *Massachusetts Institute of Technology*, “the IPAT equation is a mathematical identity that shows that the underlying environmental problems are related to ‘scale’”(2). Developed by Ehrlich and Holdren in 1970, the IPAT equation is a straightforward yet powerful tool for examining how population, economic, and technological factors interact to influence ecological outcomes.

Bangladesh offers a compelling case for applying the IPAT framework, as since its independence in 1971, the country has undergone rapid population and economic transformations. According to data from The World Bank, despite its relatively small size, Bangladesh’s population has gone up significantly since the country’s birth, making it one of the most densely populated countries in the world. During this same time period, the country has also experienced significant economic growth, especially in the past two decades as industrialization has accelerated. The combination of rising population, industrialization, and affluence has contributed to increasing levels of carbon dioxide (CO2) emissions. This could pose serious problems regarding environmental sustainability, public health, and climate change, especially for a country that is already vulnerable to climate change effects.

In this paper, I will evaluate the environmental impact of Bangladesh through the lens of the IPAT model. By analyzing historical data on population, affluence (GDP), and technology (CO2 emissions), I will assess how they shape the country’s CO2 emissions over time. This paper will not only highlight the usefulness of the IPAT model for

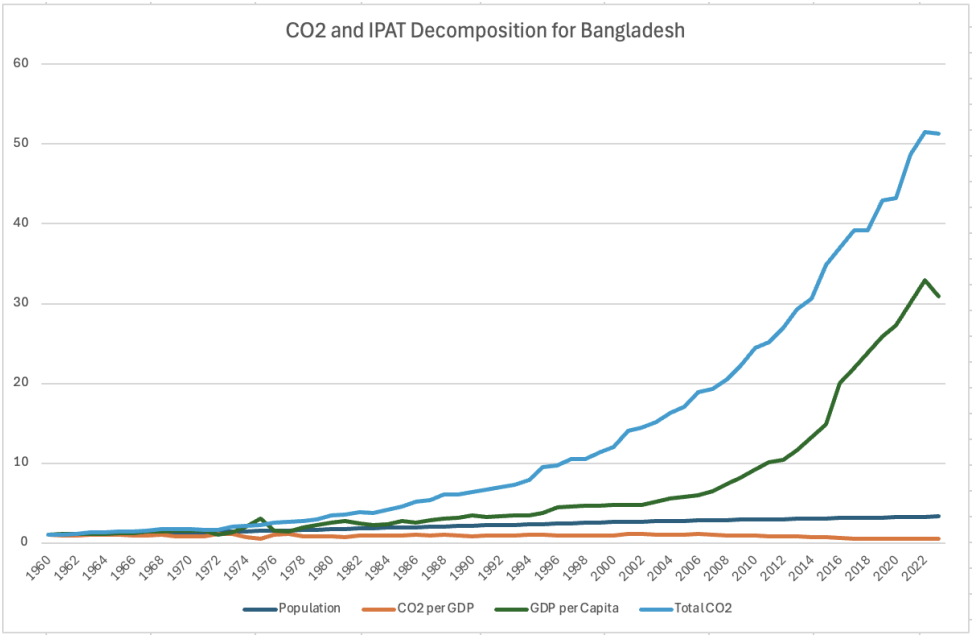
environmental analysis, but it will also seek to identify its limitations when applied to a rapidly developing country like Bangladesh.

To employ the IPAT equation, I combined the collection of secondary data with decomposition techniques in order to determine the contributions of population (P), affluence (A), and technology (T) to the overall environmental impact.

Data for this paper was retrieved from the reputable databases *The World Bank* and *Our World in Data*. The dataset used in this analysis includes annual observations for Bangladesh from 1960, a little before the country's inception, up to 2023. The variables in this iteration of the IPAT equation are population, gross domestic product (GDP), and CO2 emissions. In this case, affluence (A) is measured by GDP and GDP per capita depending on the specific calculation, and technology is derived from the ratio of emissions and GDP, expressed as CO2 per unit of GDP. This lets us judge how environmentally efficient the economy is relative to its output. And lastly, the impact (I) is represented by total CO2 emissions.

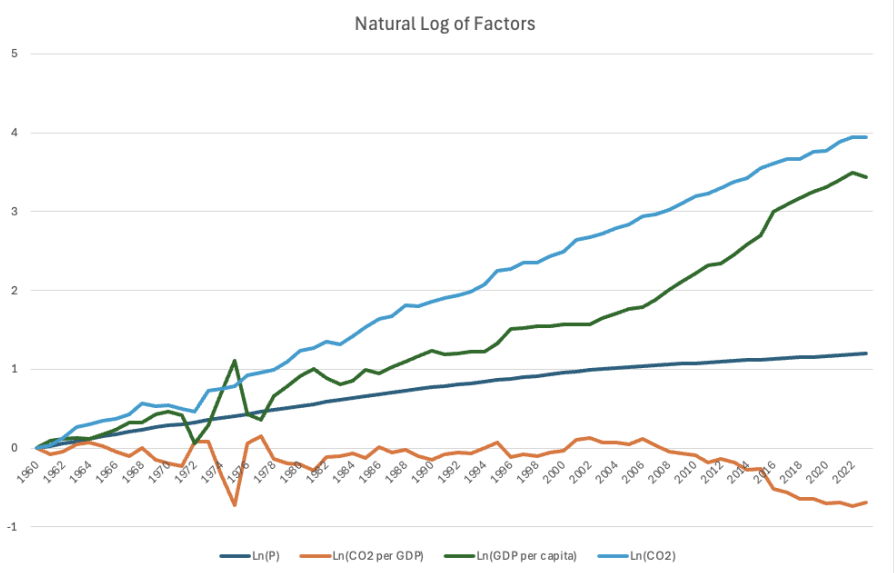
Earlier I explained how I = P * A * T. Additionally, I took the natural log of this model, calculated by ln (I) = ln(P) + ln(A) + ln(T), to see how the factors contribute to the overall impact. Using this approach, we can identify which driving factors have historically exercised the most influence on Bangladesh's environmental impact.

I will now analyze the results of implementing the IPAT model. The calculations discussed in this paper can be found in the Reference below under the name *IPAT_BNG.xlsx*. The figure to the right (*CO2 and IPAT Decomposition*) shows the growth ratios for the factors over time. As you can see, the population has experienced a steady increase throughout the



years, going from about 50 million in 1960, to 170 million in 2023. This over 300% increase is bound to put more and more strain on the local environmental systems. The affluence (GDP per capita), demonstrated a far sharper growth, especially in 2010 onward. The overall GDP grew from about $4.3 billion USD in 1960, to about $437 billion by 2023, while the GDP per capita went from $82 to about $2550 in the same time period. These numbers indicate that the nation underwent rapid economic growth and industrialization. Moving on, the impact, measured by total CO2 emissions, rose dramatically in this period as well. CO2 emissions increased from about 2.2 million tonnes in 1960 to about 113 million tonnes in 2023. This nearly 50 fold increase highlights the scale of environmental pressure Bangladesh may have to endure. Lastly, technology, measured by CO2 per unit of GDP, shows a different trend. Looking across the time period, the CO2 per GDP has actually decreased. In fact, it has halved, suggesting that there may have been improvements regarding energy efficiency and production methods. Even though emissions as a whole have drastically increased by 2023, the emissions intensity is significantly lower than its initial standing in 1960, meaning that technological improvements have mitigated, but did not outweigh, the overall effects of growth in population and affluence. Before I move on, taking another look at the graph above, it appears that impact and affluence are most similar in terms of their growth and shape. In the next section, I will look at how each factor has contributed to the overall change in impact.

By taking the natural log of the IPAT equation, we can illustrate the relative contributions of each factor. As a reminder, the equation looks like this: ln (I) = ln(P) + ln(A) + ln(T). This version of the equation allows us to look at the changes in environmental impact through the sum of changes



in population, affluence and technology over time. The figure above (*Natural Log of Factors*) shows the log transformed values of the IPAT equation's components throughout this study's time period (1960-2023). Taking a look at Ln(CO2), the light blue line, once again it is clear that CO2 emissions rise greatly over time. The dark blue line representing Ln(P) also rises over time, but at a much slower rate. Especially compared to Ln(GDP per Capita), which rose sharply, especially after 2006. The orange line, representing Ln(CO2 per GDP), stays around 0 for the most part until after 2008, where it steadily decreases. By 2023, the log transformed equation looks like this: 3.94 (I) = 1.2 (P) + 3.43 (A) - .69 (T). This figure highlights how affluence (GDP per capita) has become the primary driver of the growth in CO2 emissions in Bangladesh, while population growth contributes steadily, but not to the same extent. Meanwhile, technological advancements have acted as a mitigating factor, especially in the last 15 years, however this only partially slowed emissions growth.

Concluding this study, the IPAT model has remained as a widely accepted model for examining the relationship between human activity and environmental impact. What draws people to the IPAT equation is its simplicity. A *thwink.org* article states that "in every human interaction with the environment—even in the simplest societies—[there are] three major elements at play"(Thwink). By breaking down environmental impact into three factors, population, affluence, and technology, it allows scholars and laymen alike to clearly identify the major driving forces in environmental change. All of a sudden, analyzing long-term trends, comparing data across countries, and recognizing patterns become fairly simple tasks. Another positive regarding this model is that it requires relatively little data, making it practical for situations where there is not much data available across other sectors of interest. However, this methodology also contains limitations as well. For example, Rendell from *Inside Higher Ed* states that in regards to the IPAT model: "my objections to it, in the main, are based on my impression that it conceals at least as much truth as it reveals"(Rendell). The author goes on to say that "Technology (at least in our consumerist society) facilitates Affluence to the point of disappearing into it. Population simply cancels itself out, since Affluence is defined in *per capita* terms. And Affluence, itself, is merely a euphemism for consumption"(Rendell). By breaking down environmental impact to just three factors

overlooks the complex processes that are in play to produce these values. For example, this multiplicative relationship disregards the interactions that are occurring between these sectors. Additionally, this model does not take into account the effects of international trade and globalization, which can offshore emissions to other countries. Bangladesh has experienced this, as they have become one of the biggest garment producers in recent decades. According to Siddiqi of the *Economics Observatory*, “Bangladesh is currently the world’s second largest exporter of garments, behind only China”(Siddiqi). Furthermore, she states that: “In 1983-84, apparel accounted for less than 4% of total Bangladeshi exports. Within a decade, this share had grown to 60%, and increased to a high of 84% in 2022-23”(Siddiqi). Bangladesh becoming a global manufacturing hub surely plays a significant role in its rise in emissions. Using the IPAT model, we primarily chalked this up to GDP growth, but without diving deeper, the exact reasons would not be unveiled. Bangladesh did not increase its emissions output purely due to GDP growth, but rather due to its industrialization. In summary, this model is only capable of mapping trends, but it cannot reason what is driving them behind the scenes.

To conclude, the IPAT model is a great starting point for analyzing environmental impact. However, its simplicity limits its ability to paint a complete picture of the driving forces behind the challenges of sustainability. This study has highlighted some of the factors behind Bangladesh’s growing emissions, population and GDP, while also underlining the need to accelerate technological advancements. While the IPAT framework does not provide all the answers, it is an accessible tool for starting discussions regarding sustainability and identifying the most significant factors propelling environmental change.

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