Examining the Economic Effects of Non-Fossil Energy Policies in India

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Received January 02, 2024
Accepted June 29, 2024
Electronic access July 15, 2024

Despite its historic reliance on coal as an inexpensive and abundant energy source, India is undergoing a transition to non-fossil energy sources. The objective of this study is to investigate the relationship between India's energy policies and its economic development, and to understand what long-term impacts the changing energy landscape may have on India's economy. This paper will discuss the energy goals and policies outlined by India's Nationally Determined Contributions (NDCs) in 2016 and 2022. Although India did not fully meet these goals, the nation has made significant progress. This paper then highlights the economic growth of India and examines conflicting literature regarding the causality among energy consumption, carbon emissions, and economic growth in India. When comparing these academic studies to data drawn from the NDCs, India's government websites, and the World Bank, it can be concluded that India's energy transition is not negatively impacting the economy—a conclusion aligned with literature that finds no long-term causality. This conclusion was determined by examining India's economic growth, as well as its growth rate in comparison to that of the United States. However, given the preliminary nature of the available data, further studies and causality tests are recommended to study the longer-term impact of India's energy policies.

Introduction

Climate change is intensifying and its effects are increasingly affecting the daily lives of people across the globe. Severe weather events due to climate change, including wildfires, floods, and heat waves, are occurring at increasingly frequent rates and cause mass destruction, death, and significant financial damage. Similarly, air pollution, which is largely caused by carbon-intensive vehicle emissions, biomass burning, and fossil fuel power plants, causes over 6.5 million premature deaths each year[1]. The impact of climate change has become an increasingly urgent issue, influencing federal policymaking and stimulating national efforts to promote greater awareness.

Currently, many nations are striving to reduce their carbon dioxide (CO2) emissions and the subsequent environmental impacts. In August 2022, the United States passed the Inflation Reduction Act, which allocates $370 billion towards the clean energy transition[2]. Copenhagen, the capital of Denmark and widely considered one of the most sustainable cities in the world, has dedicated themselves to being carbon neutral by 2025[3]. India in particular plays an extremely influential role on the international stage, with its emerging economy, immense emissions, and growing geopolitical prominence. As India's population and economy develops, its environmental policies and impact will be felt by individuals and nations across the globe.

India is also internally motivated to improve its environmental standing, as India's geographic features, namely its many islands and coastal land, and its agrarian economy leave the nation particularly susceptible to climate change[4].

India has historically relied upon fossil fuels, particularly coal, to fuel its hundreds of power plants and generate electricity. As of January 2023, fossil fuels produced 70% of India's electricity, while renewable energy sources only contributed about 10% to energy needs[5]. This reliance on fossil fuels has resulted in tremendous carbon dioxide emissions. Indeed, in 2020, India was the third-largest emitting nation in the world, releasing 2.4 billion metric tons of carbon dioxide (MTCO2e)[6]. Electricity and heat account for the vast majority of carbon emissions, followed by agriculture and manufacturing. Furthermore, with over 1.4 billion people, India is now the most populated country in the world, having surpassed China on April 24, 2023[7]. In tandem with its growing population, India's economy is rapidly developing. The World Bank recently denoted India as the most rapidly developing economy when considering both the nation's aggregate and per capita GDP[8]. Given the rising population and rapid economic development, the energy demand in India is only expected to increase. The Indian government holds an unwavering commitment to its economic growth, and how India balances its economic state with its environmental pledges will be critical to the entire globe[9]. Luckily, India has significant potential to transition to clean, non-fossil energy sources, and its government is making great efforts to do so. In 2006, India's Ministry of Environment and Forests unveiled The National Environment Policy (NEP), a product of a wide array of experts that targets sustainable development while acknowledging

environmental constraints and equity components[10]. Another substantial policy was The National Action Plan on Climate Change (NAPCC), enacted in 2008, that aimed to combat the effects of climate change through eight focus areas: solar energy, energy efficiency, sustainable urban planning, water scarcity, the Himalayan mountains, afforestation, agriculture, and climate research[11]. In 2016, India ratified the Paris Agreement, joining 195 other nations on the breakthrough agreement that aims to reduce global warming to 2C[12]. In addition, since the Paris ratification, India has begun implementing a number of new policies designed to reduce their carbon emissions, facilitate the transition from coal-based to non-fossil energy sources, and improve energy access and security.

This paper focuses on India's Nationally Determined Contributions (NDCs), a set of ambitious climate goals that were originally released in 2016 and later revisited in 2022. These goals and policies target energy sourcing, particularly the transition from fossil fuels to renewable sources, and the policy changes and subsequent impacts will be examined within the last eight years. Ultimately, this paper aims to answer the following research question: How do renewable energy policies in India aim to reduce carbon emissions while maintaining economic development and widespread energy access? What may be the shortcomings of these policies on India's economic growth? drawing on the most notable and well-known studies in the literature, the relationships and causality among India's carbon emissions, energy consumption, and economic development will be investigated. As a result, this study aims to identify potential negative economic effects, and therefore, opportunities for future policy improvements. This paper will fill the gap in literature that assesses India's clean energy progress through a comparison of its progress from the 2016 to 2022 NDCs. Furthermore, this paper will uniquely serve to analyze the policy impacts through an economic lens by comparing the leading causality studies relevant to this topic. This paper also serves as a more digestible study that can uniquely serve the high school, college, or pre-professional individuals interested in these fields.

Non-fossil Energy Targets and Policies

Energy Usage and Fossil Fuels

Historically, India has relied on coal as a primary source of energy because of coal's accessibility and inexpensive nature; even among other fossil fuels, coal is one of the cheapest energy sources. From 1985 to 2015, India increased its coal production by almost eight times. Similarly, from 1950 to 1990, about 1.4 million acres of land were transformed and dedicated to coal mining[13]. The size and prominence of India's coal industry means that the transition away from coal as a fuel source will significantly impact the communities and individuals in this industry. For instance, although there were 337,4000 miners officially employed in India as of October 2023, with many sources expecting the true number of miners to be up to four times that number, it's estimated that over 100,000 coal miners will have their mine be closed within the next decade. Therefore, it is essential that policymakers also consider programs or other methods to help coal miners' transition to different industries. For instance, a more gradual transition time, such as over multiple decades, may allow coal workers to seek job opportunities in other sectors[14]. However, this tradeoff between transitioning to clean energy sources faster, and thus more effective environmental remediation, and implementing a longer transition period, which would allow the more gradual decline of the coal industry, must be carefully considered. Similarly, Sandesh Kumar Sharma, a planning member of the Central Electricity Authority, reiterated the economic value of coal, saying in 2020 that India wanted to preserve "flexible use of coal for generating power from the cheapest source of generation."[15] However, despite the appeal of being inexpensive, coal is one of the dirtiest and most carbon-intensive fossil fuels. India is making environmental progress, but because of its existing infrastructure dedicated to coal mining, India's energy demand, and the economic value in using coal, India is still attached to coal as a fuel source.

India's energy demand is predicted to increase significantly. For instance, in their 2016 study, Shahbaz et al. clearly established the causal relationship between economic growth and energy demand. Throughout their study, Shahbaz et al. primarily utilized the Bayer-Hanck cointegration test and empirical analysis. Furthermore, the paper identified urbanization as a primary factor that contributes to rising energy demands. Both strong economic development and rapid urbanization are key characteristics of India[16]. In addition, the International Energy Agency (IEA) predicted in a 2021 report that India's energy demand would increase by about 35% from 2019 to 2030 — approximately three times the worldwide average. The report was published at a time when the effects of COVID-19 were still uncertain, and before the pandemic, the IEA predicted that India's energy demand would increase by over 50

Therefore, we can understand the main obstacles India faces in its energy transition: its growing energy demand requires India to maintain a high level of energy production, and its existing coal infrastructure makes it much simpler to continue using coal as a source of fuel. Furthermore, with the close relationship between energy consumption and economic growth, India also faces the challenges of continuing its economic development throughout its energy transition. However, in response to these challenges, India's energy policies, which will be further examined later in this paper, have been made to maintain high levels of clean energy production while being mindful of potentially negative economic effects.

With India making more climate commitments but also experiencing rising energy demand, the nation must balance the need to develop non-fossil energy sources to ensure an adequate en-

ergy supply, the expenses of energy infrastructure, and heeding environmental concerns.

2016 Nationally Determined Contributions

Following their signing of the Paris Agreement in 2016, each nation was required to make, share, and uphold their Nationally Determined Contributions (NDCs), which outline specific national goals for carbon emission reduction. NDCs are a central part of the Paris Agreement, and a primary method to ensure that all nations are collectively working towards achieving the 2.0°C global warming goal[17].

In 2016, India released its first set of NDCs, which set goals, created new programs, and revamped existing policies in several categories. The main areas of focus were electricity generation capacity from clean energy sources, increasing carbon sinks, maintaining economic development, establishing a national smart grid, and reducing their emissions intensity relative to GDP[4]. For instance, the National Air Quality Index, the National Smart Grid Mission, and the Smart Cities Mission were some of the several new policies that were implemented by the NDCs, while the National Solar Mission and the Green Generation for Clean & Energy Secure India were pre-existing policies that were rapidly scaled up. It is also important to note that while the NDCs are the ultimate goals that India endeavors to meet, the actual means to do so are dependent upon policies and programs, many of which are outlined within the NDCs[4]. References that this paper makes to the NDCs as 'policies' are references to the policies and programs outlined within the goals.

Goals for India's clean energy transition were particularly central to the 2016 NDCs. India aimed to have 40% of their electricity generation capacity be from non-fossil energy sources by 2030. A sub-target of this goal was to have 175 gigawatts (GW) of electricity generation capacity be installed by 2022, including 100 GW of solar energy and 60 GW of wind energy. India also targeted energy sourcing of the transportation sector by declaring a goal for 5% of railway energy to be generated from biodiesel, a renewable and biodegradable fuel. The NDCs did acknowledge India's heavy reliance on coal, as 167.2 GW — almost 61% — of India's installed capacity in 2016 were from coal power. While it would be difficult for India to transition off of such a large power source, a fact acknowledged by the NDCs, the nation still outlined efforts to at least improve the efficiency of coal power. In addition, India's goals for clean energy sources included provisions for greater use of biomass, hydropower, and nuclear power as energy sources[4].

Beyond the emission reductions commitments that were required by the Paris Agreement, India also outlined a series of goals relative to their economic status. Compared to their 2005 standing, India aimed to reduce their emission intensity relative to GDP by 20-25% by 2020 and 33-35% by 2030[4]. In addition, India acknowledged the common conception that economic growth will inherently harm the environment. However, the nation simultaneously pushed back against this idea, reaffirming their commitment to economic development alongside the environment.

Impacts of the 2016 NDCs on Energy Sources

Overall, based on data taken from 2021-2022, India has made substantial progress towards their 2016 NDCs goals. The nation has successfully begun their energy transition to non-fossil electricity sources, increased the use of solar energy, created net removal of carbon via afforestation, and reduced their emission intensity relative to GDP.

As seen in Figure 1, India's non-fossil electricity generation capacity did improve, although it did not meet the targets of the 2016 NDCs. In 2016, 94.5 GW, or 31% of the total generation capacity, was from non-fossil sources. The target established in 2016 was to have 40% of total generation capacity be from non-fossil sources; by 2022, 42% of the total was from non-fossil sources. The renewable electricity generation capacity in 2016 was 148.5 GW, with a goal of 175 GW; India achieved 165 GW of renewable generation capacity by 2022. Solar Generation Capacity also improved. Starting at 8.5 GW in 2016, the NDCs aimed to increase to 100 GW; in 2022, India had installed 60.8 GW of solar generation capacity. Furthermore, of the total energy capacity in 2022, 11.8% was hydropower, 10.5% was wind power, and 1.7% was nuclear power[9].

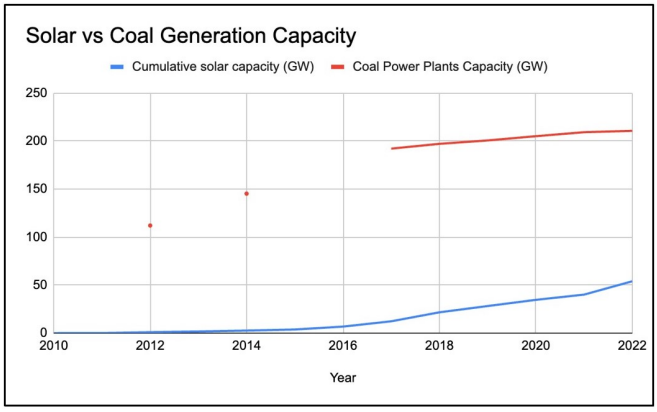

Fig. 1 Solar vs Coal Generation[14?]

Figure 1 outlines the quantity of installed solar energy capacity in GW over the course of 2010-2022, highlighting India's successful efforts to increase solar capacity. For instance, in 2016, before the NDCs were released, India's installed solar energy capacity was 4.06 GW; by 2022, there was 53.99 GW of installed solar capacity, which is over thirteen times the previous amount.

To put these values into perspective, solar generation capacity is compared to the available data on coal-based power plants

	2016 Amount	2016 NDCs Goal	2022 Amount
Non-Fossil Generation Capacity	94.5 GW, 31% of total	40% of total	42% of total
Renewable Generation Capacity	148.5	175 GW	165 GW
Solar Generation Capacity	8.5 GW	100 GW	60.8 GW

Table 1 Three of the main goals from the 2016 NDCs, as well as the actual progress achieved by 2022.[9].

and their generation capacity. While coal still significantly outsources solar energy, progress for solar energy has been made, especially since the 2016 NDCs.

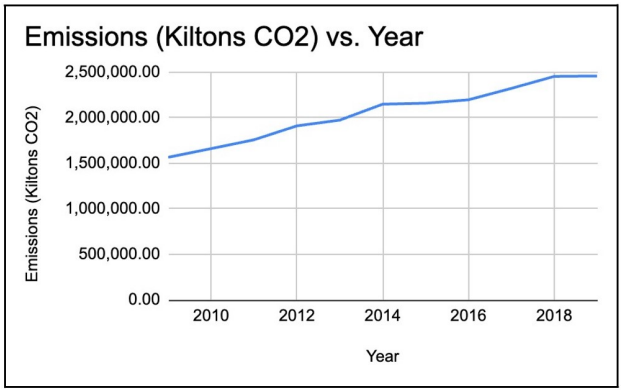

Fig. 2 Emissions (Kilotons CO2) vs Year[18]

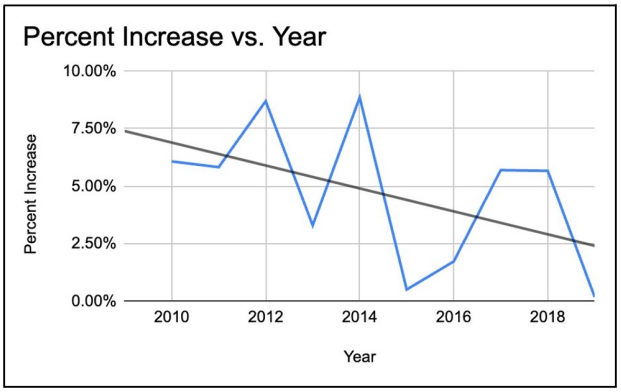

Fig. 3 Percent Increase vs Year

Figure 2 and Figure 3 represent the total CO2 emissions produced by India and the percent increase of emissions each year, respectively. While India's carbon emissions continue to grow each year, as shown in the increasing line in Figure 3, the rate at which they're increasing has begun to plateau. This trend is exemplified in Figure 4, where despite the variance from year to year, the general trend in the percent increase of carbon emissions each year is declining.

Therefore, it is demonstrated how the overall goal of India's NDCs, which is to reduce their carbon emissions in order to limit global warming, is succeeding.

Revised Goals in the 2022 NDCs

As part of the Paris Agreement, nations are required to reevaluate their NDCs every five years; therefore, in 2022, India reviewed their 2016 NDCs and submitted revised goals to the UN in August 2022.

India maintained the central areas of focus in their NDCs, which included greater non-fossil electricity generation, implementing more carbon sinks, and seeking international funding. However, they made three significant changes to specific goals.

With the energy transition to non-fossil sources, India stated the new goal of having 50% of their installed electricity capacity be from non-fossil sources by 2030. Previously, India aimed for 40% non-fossil sources by 2022, although they only achieved 31%[8]. In addition, India's new NDCs wanted to reduce their emissions intensity relative to GDP to 55% of 2005 levels by 2030. Previously, in 2016, carbon emissions relative to GDP were at 76% of 2005 levels, and by 2022, the intensity dropped to 66% of 2004 levels. India also declared their goal of being net-zero by 2070 in the revised NDCs[19].

In addition, while the 2022 NDCs focused primarily on energy and environmental goals, the document did acknowledge the potential impacts on the Indian economy. India said it would aim to enact these energy policies while maintaining their level of economic growth, and that these more sustainable energy practices can be applied to the major parts of India's economy[19].

Challenges of Meeting India's NDCs

As previously established, India did not meet their target numbers from their 2016 NDCs. This gap is due to the variety of challenges that India faces, particularly their growing energy demand and hesitancy to implement legislation that would lead to economic decline. Additionally, India faces the extremely large practical challenge of energy infrastructure. They already have an immense amount of existing coal infrastructure, such as mines and power plants, but as displayed in Figure 1, the capacity of solar facilities is still far behind. Furthermore, while India released their climate commitments and goals in their NDCs, these policies do not address the issue of new energy facilities. Similarly, although India's revised NDCs did extend their goals for clean energy production, their 2022 commitments did not

directly address their previous goals nor the challenges they faced when implementing them[19].

Economic Development and Economic Impacts of NDCs

Overview of India's Growing Economy

India's economy is predicted to grow rapidly in the next several decades. Based on 2021 data and nations' GDPs, Goldman Sachs Research estimated that by 2075, India will be the second-largest economy in the world, following China and just above the third place United States[20].

India's economic development is driven by several factors, including their young and increasing population, as well as their emerging innovation and technology. India's population is primarily composed of younger individuals. India's dependency ratio, which compares the number of people in the working force to non-working dependents, such as children and the elderly, is relatively low when compared to other large economies. Therefore, if India is able to successfully build their labor force, the nation has a higher capacity to increase manufacturing, consumption, and services. In addition, India's innovation and technology is advancing, leading to increased efficiency and manufacturing output[20].

Over the past two decades, India's GDP, measured in U.S. dollars, has grown steadily.

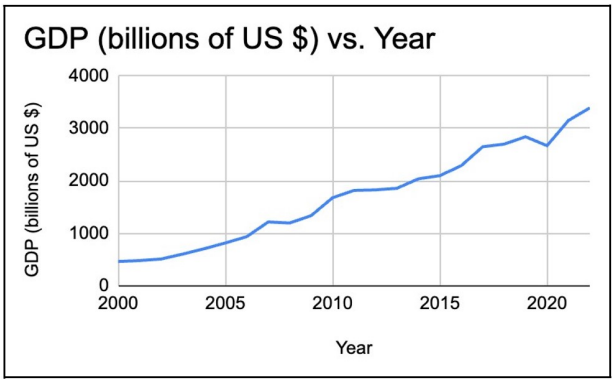

Fig. 4 GDP[21]

Figure 5 denotes India's GDP from 2000 and beyond. From this graph, it is clear that India's GDP is growing steadily. Furthermore, Figure 6 exhibits the annual percent change of India's GDP compared to that of the United States. Despite the yearly variation, it is clear how India's economy is growing at a relatively high rate.

Causality among Energy Policies, Economic Development, and Carbon Emissions India's economy is affected by the emerging energy policies. As previously established, energy demand

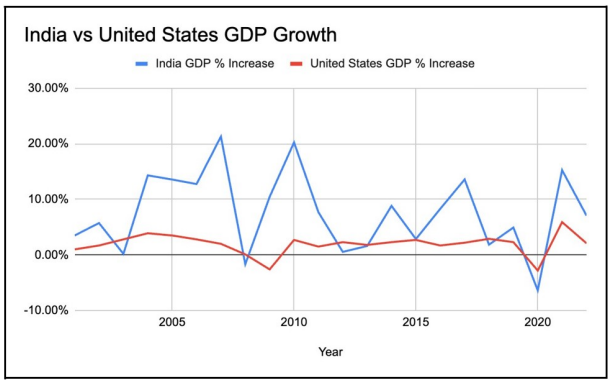

Fig. 5 India vs USA GDP[22]

and consumption is strongly correlated with economic development and growth, meaning that the effectiveness of the energy policies in both transitioning to non-fossil sources and generating adequate energy will have significant effects on the economy. Thomas Spencer, a contributor at the International Energy Agency, said, "Historically, countries that have achieved substantial and rapid transitions away from coal-fired power tend to have had either slowly growing or stagnant or even slightly declining electricity demand"[5]. In other words, one of India's primary challenges continues to be balancing its rapid economic development, and the associated energy demand, with its goals to transition towards non-fossil electricity generation.

Conflicting Literature

Since the late 1900s, when researchers like John Kraft and Arthur Kraft made influential conclusions about causality between energy and economic growth, there has been a growing body of literature surrounding India's economy and energy policies[23]. For the purposes of this paper, the causal relationship between three main factors will be examined: energy usage, carbon emissions, and economic growth, measured by income and GDP.

The literature strongly establishes the close relationships among these central factors. Even from a solely intuitive standpoint, it is understandable how greater energy consumption from fossil fuel sources contributes to greater carbon emissions. Similarly, it is intuitive that economic growth is closely related to the energy use in a nation; many manufacturers require energy for machines and productions, and in turn, economic growth can facilitate the need for more production and thus energy. Even for economic growth and carbon emissions, which may not seem to be closely related at first, the connection of each to energy consumption may facilitate extended sequences of causes and effects.

This paper will examine the causal relationships determined in studies using specific economical and statistical methods;

the most referenced and well-known articles in this category of literature were selected. This paper will analyze these results and explain scenarios that support these conclusions. In addition, some caveats surrounding these studies will be shared, especially regarding the data used in each model, as well as implications for India's economy and energy landscape. Among existing literature, there were surprisingly contradictory findings about specific aspects of the causal relationships. In addition to mixed findings on the existence of causality relationships, there are also variations in short-term versus long-term relationships and unidirectional or bidirectional causality.

There are two main categories of findings that will be discussed. The first collection of literature produces findings of causal relationships among energy consumption, economic growth, and carbon emissions. For instance, in 2014, Yang & Zhao utilized out-of-sample Granger causality tests and Directed Acyclic Graphs (DAG) to find bidirectional causality between carbon emissions and economic growth, unidirectional Granger causality from energy consumption to carbon emissions, and unidirectional energy consumption to economic growth[24]. Other studies have provided similar results, utilizing a variety of methods like the EG Representation Theorem[25] and an adaptation of the Engle-Granger cointegration test29. Fatai et al. shared the close relationship between energy consumption and real GDP growth, as well as the unidirectional causality between energy consumption and income[25]. In this case, income is an indicator of nationwide economic progress. Asafu-Adjaye similarly found unidirectional Granger causality from energy to economic development, also represented by income.

One explanation for the linkage between carbon emissions and economic growth could be the connection to the most profitable industries. In recent years, less carbon-intensive industries like agriculture have begun to decline as a revenue source, while other industries, like mining, technology, petrochemicals, and automobiles are rapidly growing and taking greater roles in India's economy[26]. As India's economy grows, so does its more carbon-intensive industries, thus raising the nation's overall emissions. Similarly, as the carbon emissions of these industries increase, there will be greater economic output. In addition, it is easy to understand how energy consumption, especially energy generated from fossil fuel sources, causes carbon emissions. Especially when considering the timeline of these older studies used, non-fossil energy sources would barely have been in use. The causality from energy consumption to economic growth also seems intuitive. Electricity fuels transportation, powers production systems, and enables labor, as well as a multitude of other benefits. Even from a historical standpoint, energy and electricity are tightly associated with industrialization, infrastructure development, and economic growth[27].

However, along with understanding the stories that can explain the causal relationships, it is also necessary to examine the robustness and consider the caveats of these results. The two primary caveats that surround this literature are the nature of the relationship between carbon emissions and economic growth, as well as the data used in each model. Typically, when studying causality, the two variables are distinct. For example, if a policymaker were to research the causality between solar panel pricing and household cooking fuels, the datasets for each would be separate. In the case of carbon emissions and economic development, however, the same set of industries are tied to both emissions and economic output. Therefore, it is difficult to understand how one variable, either emissions or economic output, can cause the other without the intermediate influence of the industries.

In addition, the time series data used in each study are annual measurements at a national level and have their own inherent limitations. These broad-scale datasets are used to provide insight into the entire nation's development, but that also means the data reflects unrelated and even misleading changes. For instance, changes in real GDP may be related to inflation, the labor workforce, or international trade. Therefore, a statistical model including the real GDP data and energy consumption, for instance, may inaccurately identify energy consumption as the cause of real GDP changes.

Another shortcoming of the data used is that it is relatively outdated in each study. Yang & Zhao used a time span of 1970-2008, Fatai et al. studied data from 1960-1999, and Asafu-Adjaye had a 1973-1995 window for their data[24,25,28]. These datasets are appropriate for the studies in which they were used, as the statistical models used in these studies examined change over time, which requires data points from many years. However, there have been significant changes, particularly since the 2016 NDCs, in India's energy consumption and prevalence of non-fossil energy generation. Therefore, the results of these studies may not accurately reflect the current relationships and casualties. For instance, as time progresses and technology develops, the costs of the solar panel installation in India has decreased significantly[29]. Models utilizing more recent data may yield different results, especially regarding the relationships involving economic development and financial costs.

While the results should be fairly caveated, there are still several conclusions that can be drawn from this side of the literature. Under the assumption that the results establishing causality are accurate, the linkage between carbon emissions and economy suggests that the reduction of carbon emissions, which would be the scenario under India's energy policies, will negatively impact India's economy. For instance, if industries were forced to cap their carbon emissions at a certain amount, they may have to reduce production, which would negatively affect the economic output. However, the causality from energy consumption to economic growth implies that if India's energy demand can be satisfied by non-fossil sources, their economy can maintain its level of development.

Within the other narrative established in the literature, it is

agreed that carbon emissions and energy consumption share causality, as carbon is inherently involved in fossil fuel energy production. However, this collection of literature finds no causality between energy consumption and economic growth, or between carbon emissions and economic growth. Ghosh's 2010 study found that there was no causality from energy supply to economic growth. While the study did reveal a short-term unidirectional causality from carbon emissions to economic growth, they also found that the same long-term causal relationship did not exist. Ghosh employed a variety of statistical and economic strategies, including ARDL bounds testing and the Johansen-Juselius maximum likelihood procedure[30]. Alam et al. shared similar findings, acknowledging that energy consumption and carbon emissions do share causality, especially since at the time of the paper, India relied almost completely on carbon-intensive fossil fuel sources. Alam et al. found that there was short-term causality between carbon emissions and real income changes, but not a long-term relationship. Similarly, while their model implied that there was some level of causality in the short-term, they found no causality between energy consumption and real income changes in the long-term[31].

Several explanations support these results. While India's mining, technology, and service industries are growing rapidly, India is still primarily an agrarian economy, with about half its labor force working in agriculture[32]. This agrarian component can explain the lack of causality between energy supply and economic growth; agriculture typically prioritizes fertile land and a stable water supply over electricity. In addition, energy security may also decrease the economic impacts. A wide-reaching electricity grid that is not reliable will not be as effective in helping individuals work and consume, meaning the economic benefits may be reduced. Furthermore, in the long-term, as India continues to increase their solar generation capacity, more energy capacity and consumption will originate from renewable sources. The costs of energy storage and energy infrastructure installation are also predicted to decrease in the long-run, meaning this increased energy consumption from renewable sources will not impact India's economy as strongly.

As with other articles in the literature, there are several strong caveats surrounding these studies, particularly with the data used. Ghosh and Alam et al. both used annual time series data, which leads to issues with generalization as outlined previously[30,31]. Furthermore, both studies used data from 1971-2006, simply due to the lack of availability of other time series data. In future research, more specific studies that utilize more frequent data collection points, such as monthly instead of annual measurements, would help resolve this issue; this method would provide sufficient entries in the same models and statistical tests but would not have to incorporate data from as far back. In addition, one of the key aspects of this 'narrative' in the literature is the lack of causality in many long-term relationships. Long-term relationships are inherently more difficult to predict, and they also exacerbate the issue of broad datasets encompassing other variables. For instance, all these studies were conducted before India's NDCs drastically changed the energy landscape. It is difficult for long-term relationships to be extremely robust, as significant policies, new technologies, and so many other related factors are impossible to foresee.

However, this side of the literature can still provide several implications. Ghosh found no causality from energy supply to economic growth, and similarly, Alam found no long-term causality between energy consumption and real income changes[30,31]. However, it is important to note that energy supply does not equate to actual usage. Therefore, beyond increasing renewable energy capacity and supply, there need to be policies in place that shift the actual usage of energy sources. In addition, it may be beneficial for India to transition energy sources gradually, in order to avoid the negative short-term impacts on the economy. Then, with the increased supply and consumption of non-fossil energy, India's economy will ultimately grow while also reducing their carbon emissions. Furthermore, the lack of long-term causality from carbon emissions to economic growth suggests that India is capable of significantly reducing their emissions without harming the economy.

Overall, one of the main differences between these two narratives will be the economic cost of non-fossil energy. Obviously, as renewable energy sources become less expensive, industries, companies, and individuals will be more incentivized to transition sources. Especially for India, a nation that valued coal because of its lower expense, reducing costs of renewable energy will be an important task. However, practically speaking, it may not be plausible for renewable energy to reach such costs without government subsidies, foreign investments, and continual revisions to India's energy policies. Another influential factor may be the role of agriculture compared to manufacturing and services as India's economy develops. These dominating industries will help determine India's future energy demand, which in turn will affect energy costs, sources, and consumption. Furthermore, the main distinctions between the two narratives is the long-term causality between emissions and the economy, as well as energy consumption and the economy. Therefore, the main difference in policy implications is that India would be more encouraged towards the clean energy transition if there is no long-term causality. In this scenario, even if there are initial costs of installing and using clean energy sources, the ultimate results would benefit India economically and environmentally.

Discussion

Overall, India has made notable progress towards its non-fossil energy commitments, and despite the close relationship among coal usage, energy consumption, and economic growth, India's current status seems to align with the body of literature that disregards any long-term causality or harm between India's

energy transition and the nation's economic development.

India's renewable energy goals are extremely ambitious, and while it has not met all their stated goals, India has made significant progress in its clean energy efforts. The nation has installed a significant amount of non-fossil electricity generation capacity, and it has also reduced its rate of carbon emissions. Beyond its domestic progress, India is the nation with the third-fastest increase in renewable generation capacity[33].

Given its growing economy, rising energy demand, and historic reliance on coal, it was expected that India's energy goals would harm its economic development. However, India has affirmed its commitment to its economic development throughout their energy transition. As seen from the data in Figure 5 and Figure 6, India has not exhibited signs of economic decline.

Collectively, these results seem to align with the second narrative in the literature, which finds no causality between energy consumption and economic growth, or between carbon emissions and economic growth. In other words, it currently seems as though India's rapid upscale of non-fossil energy sources will not inflict long-term harm on the economy.

It must be noted that these results are still preliminary, as the implementation of the NDCs is still fairly recent. In future years, as more post-2016 data regarding India's carbon emissions, renewable generation capacity, fossil fuel usage, and economic growth becomes available, more causality studies will provide more robust insights. In particular, depending on how renewable energy is actually installed and consumed, the relationship between carbon emissions, growing industries, and economic growth is likely to be affected.

Methods

Throughout this paper, data regarding India's NDCs and renewable energy progress was taken directly from India's government websites when available. Official documents sourced through the United Nations were used to find the original and revised NDC targets. Most economic data, such as annual GDP growth, was drawn from the World Bank, and other sources, such as the International Energy Agency and Goldman Sachs Research, were used to find otherwise unavailable data. All of the data used in this paper was publicly available, so data collection from these sources was fairly straightforward. This data was then carefully imported into a singular spreadsheet. Within the literature, key words such as "energy consumption," "energy policies," "economic growth," and "India" were used to search for articles. From the results, the most cited articles were selected for the literature review, since the findings of these studies will be the most well-known and shared. For instance, Google Sheets chart generator feature was used to graph data and create Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6; axis scales and titles were then manually inputted. In Figure 4, the line of best fit was computer-generated and then displayed in a different color.

Conclusion

India's energy policies are extremely ambitious, with lofty goals regarding non-fossil electricity generation capacity and solar energy. While not entirely realized, India has made substantial progress towards its 2016 goals, and the nation updated its NDCs in 2022 with even more ambitious targets. In the time following the NDCs, India has retained its level of GDP growth, reflecting a strong economy that is unaffected by the energy policies. Therefore, out of existing literature in this field, India seems to be in line with the studies that find no long-term causality between carbon emissions, economic growth, and energy consumption.

A current investigation into India's energy policies and economic effects is relevant and insightful, especially since the NDCs mark a turning point in India's energy landscape. For the same reason, as time progresses and more data becomes available, there will be better insight into the relationships among energy consumption, carbon emissions, and economic growth. Therefore, this paper recommends future research and frequent reassessment of renewable energy generation, carbon emissions, and economic growth; in particular, future research utilizing more recent and frequent data measurements, as opposed to annual time series data will provide a better sense of India's trajectory.

Policymakers should be attentive to emerging studies and implement the necessary legislation to support and complete the energy transition. The government should subsidize and invest in renewable energy facilities and infrastructure, and as this sector continues to develop, the government should continue to emphasize job creation to grow India's economy. Relatedly, policymakers must also pay attention to coal mining communities and support the transition of these workers into other sectors. It is essential that India be able to develop economically while transitioning away from fossil fuel energy sources—not only for India as a nation, but for the climate future of the entire world.

Acknowledgments

I would also like to acknowledge and thank Dr. Eric Hsu for his feedback and guidance throughout the writing of this paper.

References

1 *World Health Organization.*

2 *International Energy Agency*, 16156– – – – –2022.

3 *Copenhagen." Carbon Neutral Cities Alliance, carbonneutralcities.org/cities/copenhagen/*.

4 *Ministry of Environment, Forest and Climate Change, Government of India, "India's intended nationally determined contribution: Working towards climate justice*.

5 S. Arasu and M. Wildeman, *AP News*.

6 B. A, *Investopedia*, 092915 5– – – – – – 2.

7 *UN Department of Economic and Social Affairs, "UN DESA Policy Brief No. 153: India overtakes China as the world's most populous country*.

8 A. Mishra, *Business Standard*, – – – – – – – – – – – – –123060601010 1.

9 K. Deb and P. Kohli, *Columbia Center on Global Energy and Policy (2022),https://www.energypolicy.columbia.edu/publications/assessing-india-s-ambitious-climate -commitments/*.

10 *National Portal of India*, – – –2006.

11 H. Pandve, *Indian Journal of Occupational and Environmental Medicine*, **13**, 17–19.

12 *BBC News*, – – –37536348.

13 S. Kuruganti, *India International Centre Quarterly*, **42**, 72–106.

14 R. Tate, D. Mei, T. Means and S. Sugaya, *Global Energy Monitor*.

15 *Central Electricity Authority*.

16 M. Shahbaz, H. Mallick, M. Mahalik and P. Sadorsky, *Energy Economics*, **55**, 52–68.

17 United Nations Framework Convention on Climate Change,https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs.

18 21., *World Bank Open Data*.

19 *Government of India, "India's updated first nationally determined contribution under Paris Agreement*.

20 *Goldman Sachs*, – – – –2075– – – – –.

21 *World Bank Open Data*.

22 *World Bank Open Data*.

23 J. Kraft and A. Kraft, *The Journal of Energy and Development*, **3**, 401–403.

24 Z. Yang and Y. Zhao, *Economic Modelling*, **38**, 533–540.

25 K. Fatai, L. Oxley and F. Scrimgeour, *Mathematics and Computers in Simulation*, **64**, 431–445.

26 V. Page, *Investopedia*, 043015 – – – – –.

27 X. Shengfeng, X. Sheng, Z. Tianxing and Z. Xuelli, *Physics Procedia*, **24**, 56–62.

28 J. Asafu-Adjaye, *Energy Economics*, **22**, 615–625.

29 J. Wood, *World Economic Forum (2019), www.weforum.org/agenda/2019/06/india-is-now-producing-the-world-s-cheapest-solar-p ower/*.

30 S. Ghosh, *Energy Policy*, **38**, 3008–3014.

31 M. Alam, I. Begum, J. Buysse, S. Rahman and G. Huylenbroeck, *Renewable and Sustainable Energy Reviews*, **15**, 3243–3251.

32 *International Trade Association. "India - food and agriculture value chain*, `https://www.trade.gov/country-commercial-guides/india-food-and-agriculture-value-chai`.

33 *International Renewable Energy Agency, "Installed renewable electricity capacity (MW) by region/country/area, technology and year*.