Economics of Global Warming

Dibyendu Maiti*

Context: A Tale of Two Crises

During the last couple of decades, the pace of human progress has been severely threatened by two swords of crises — global warming and economic recession. They are moving hand in hand. The immediate question is whether there is any connection between them. The world economy progressed fast after the Industrial Revolution, which originated in Europe during the 17th and 18th centuries, but experienced a gradual deterioration of the global environment, as revealed during the last couple of decades when industrial activities expanded to other parts. The Industrial Revolution has liberated the individual from an orthodox feudal system. This enables individuals to accumulate capital for the technological change required for economic growth, which brings ease, convenience, and comfort to human livelihoods. In the process, it exploits fossil fuels and deposits carbon content in the atmosphere.

Global warming, influenced by the increase in greenhouse gas emissions as a result of the consumption of fossil fuels, has a wide range of consequences, affecting the environment, human health and economies worldwide. These consequences include rising sea levels, more frequent and severe extreme weather events, disruptions of ecosystems, and health impacts such as increased heat-related illnesses and the spread of infectious diseases. These changes damage agriculture, infrastructure, assets, and the productivity and efficiency of labour, leading to various challenges to human life in society, both at the individual and aggregate levels. A typical capitalist economy aiming to grow fast often ignores the problem of global warming and its consequences on socio-economic changes individually as a nation. This article aims to disentangle the fundamental economic forces that worked for industrialization at the cost of the environment in the present form of world order.

Since 1880, the global annual temperature has increased at an average rate of 0.07°C (0.13°F) per decade, and this rate has accelerated to an average of 0.17°C (0.31°F) per decade from 1980 onward (see Figures 1 and 2). The present world is around 1.2°C warmer than the pre-industrialization period due to human-caused factors. Various extreme climatic events are occurring throughout the world, including catastrophic floods, devastating heatwaves, and record-breaking wildfires. Russia witnessed catastrophic floods in 2023. China and the United States witnessed high temperature events, and India reported numerous fatalities due to heatstroke in the same year. Libya experienced destructive floods, and a severe storm in Myanmar caused significant damage and loss of life. A major cyclone in Southeast Africa, including Cyclone Freddy, caused significant loss of life and displacement of residents. Europe experienced heat waves that resulted in record high temperatures

*Dr Maiti is a Professor at the Delhi School of Economics

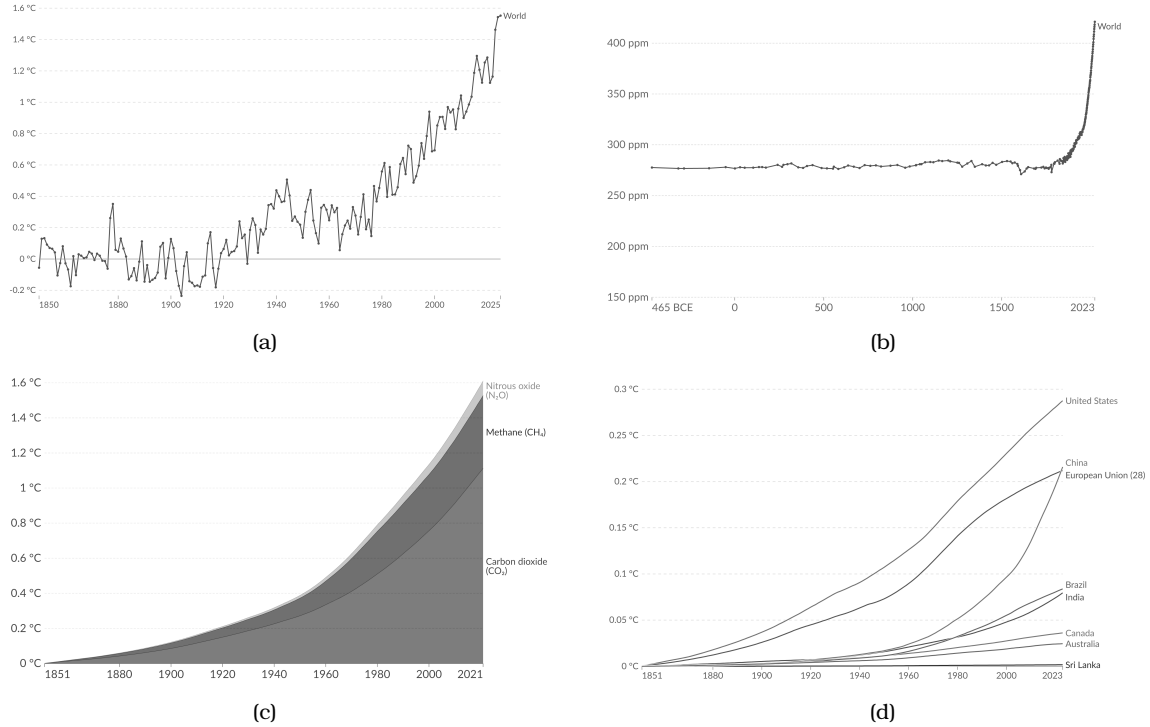

Figure 1: Current Shifts in Climate Change across the Globe. (a) Global warming: annual temperature anomaly. Note: The difference in average land-sea surface temperature compared to the 1861-1890 mean, in degrees Celsius. Data source: Met Office Hadley Centre – HadCRUT5 (2025). (b) Global Atmospheric CO_2 concentration. Note: Global Atmospheric CO_2 concentration is measured in parts per million (ppm). Long-term trends in CO_2 concentration can be measured in high resolution using preserved air samples in ice cores. Source: National Oceanic and Atmospheric Administration. (c) Contribution to global mean surface temperature rise by gas, World, 1851 to 2023. Note: The global mean surface temperature change as a result of a country or region's cumulative emissions of three gases — carbon dioxide, methane, and nitrous oxide. This does not include cooling impacts from sulphur dioxide and aerosols, so the net warming. Source: Jones et al. (2024). (d) Contribution to global mean surface temperature rise, 1851 to 2023. Note: The global mean surface temperature change as a result of a country or region's cumulative emissions of three gases — carbon dioxide, methane, and nitrous oxide. Source: Our World In Data; https://ourworldindata.org/data

in 2024, and Delhi witnessed more than 50°C in the summer of 2024. Deadly floods severely hit much of central Europe in 2024, including Poland, the Czech Republic, Romania, Austria, and Italy. Several examples of such extreme events can be cited.

These concerns demanded the protection of the environment have increased throughout the world. The political and social awareness of global warming began in 1962 when Rachel Carson, a marine biologist, exposed the environmental devastation caused by indiscriminate pesticide use and the government's failure to regulate and protect public health and wildlife.

It received momentum with the call to celebrate Earth Day to protect all life on Earth and the formation of the *Friends of the Earth* organization in 1970. In response to such activism, manufacturing began to shift the production of toxic and dirty goods

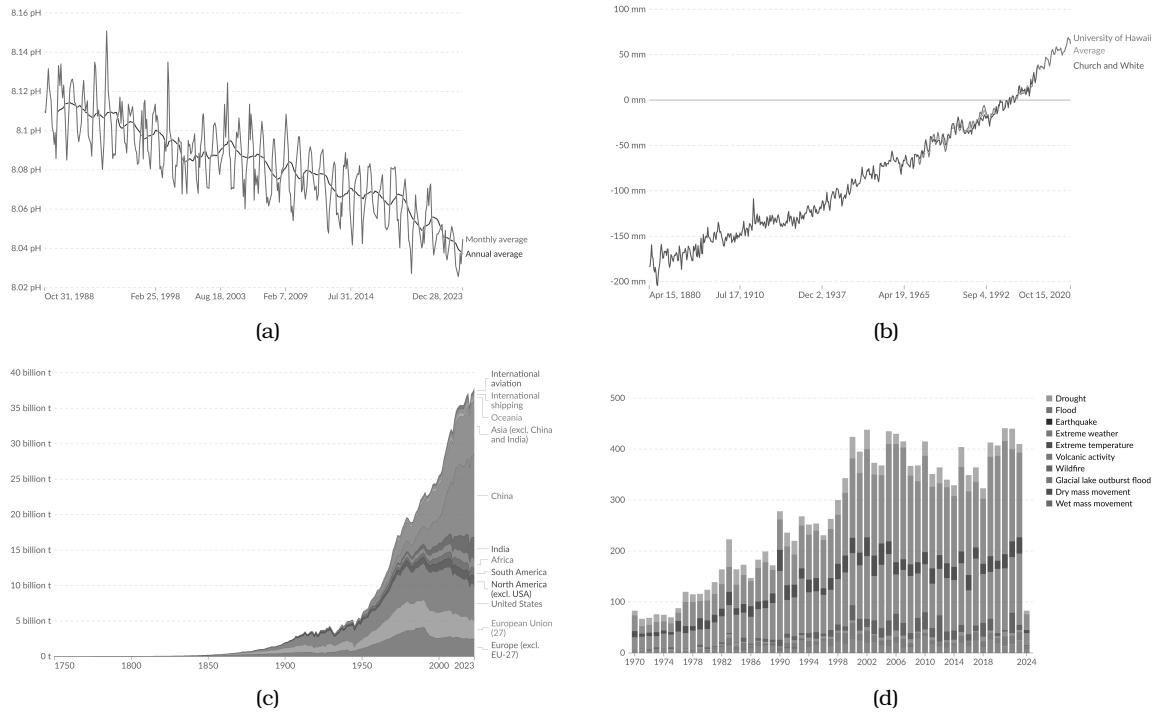

Figure 2: Global Climate Change Dynamics. (a) Ocean acidification: mean seawater pH, Hawaii Note: Mean seawater pH is shown based on in-situ measurements of pH from the Aloha station in Hawaii. Source: School of Ocean & Earth Science & Technology – Hawaii Ocean Time-series (2024). (b) Sea level rise Global mean sea level rise is measured relative to the 1993–2008 average sea level. This is shown as three series: the widely-cited Church & White dataset; the University of Hawaii Sea Level Center (UHLSC); and the average of the two. Source: NOAA Climate.gov (2022) (c) Annual CO_2 emissions by world region Note: Emissions from fossil fuels and industry are included, but not land-use change emissions. International aviation and shipping are included as separate entities, as they are not included in any country's emissions. Source: Global Carbon Budget (2024), OurWorldinData.org/co2-and-greenhouse-gas-emissions. (d) Global-reported natural disasters by type, 1970 to 2024. Note: The annual reported number of natural disasters, categorised by type. The number of global reported natural disaster events in any given year. Note that this largely reflects increases in data reporting and should not be used to assess the total number of events. Source: EM-DAT, CRED / UCLouvain (2024)

from developed to less developed countries. Gradually, the activities went beyond the national boundary and gave shape to the United Nations Framework Convention on Climate Change (UNFCCC) to draw common agreements against environmental challenges, which offered a couple of guidelines to follow. Due to the limited success of such guidelines, the Montreal Protocol in 1987 prescribed a bottom-up approach to draw a common consensus. In sequence, the largest translation took place with the formation of the Climate Action Network in 1992, which received membership from Greenpeace, WWF, Oxfam, Friends of the Earth, and others. This resulted in the first United Nations Climate Change Conference in 1992 in Copenhagen, which could not draw any broad agreement for environmental mitigation due to the lack of consensus.

Later, the 1997 Kyoto Protocol of the UNFCCC set out the binding targets of emission reduction commitments for the countries, which has, however, hardly

been implemented in the absence of any coordination and governance mechanism. Between 2006 and 2009, the campaign against climate change raised fresh and serious concerns about the commitment to emissions. It urged governments to make more meaningful attempts to address climate change.

Finally, the Paris Agreement, which was reached in 2015, succeeded the Kyoto Protocol in reducing the emission of carbon dioxide and five other greenhouse gases, and suggested carbon emissions trading between sectors or countries if they maintain or increase emissions of these gases. But that ended in 2020. However, the Paris Convention has led many countries to make commitments for strategies that aim to zero carbon emissions between 2050 and 2070. But, success remained elusive due to the paucity of funds for green investments and the lack of international governance and coordination.

It is evident that the concerns raised at several global conventions and conferences have not been addressed and the adopted protocols have not been strictly implemented in many countries. The Paris Climate Accord is an agreement involving more than 180 countries to reduce greenhouse gas emissions and limit the global temperature increase to less than 2 degrees Celsius (3.6 degrees Fahrenheit) above the preindustrial level by the year 2100. On 20 January 2021, then-President Joe Biden signed an executive order for the United States to rejoin the Paris Agreement after Donald Trump's first presidential administration withdrew from it on 4 November 2020. Trump returned to office in January 2025 and withdrew the US from the Paris Agreement again. The newly elected president is more concerned about the recovery of the US economy from the prolonged recession after the global financial crisis in 2008. This move has shattered all hopes.

Similarly, other emerging countries face various development challenges and have barely been pursuing strategies to curb carbon emissions and climate change, even after committing to a goal for the zero-carbon emission target on paper. It is the severity of COVID-19 that has threatened human survival in recent times. Therefore, the immediate question is: Can we sustain growth and progress without addressing the global climate crisis? The answer to this question is very relevant now, as most nations are taking measures to accelerate the pace of industrialization to overcome the current phase of prolonged economic recession.

Undoubtedly, the world economy is going through severe economic distress and turmoil. The problem is not only for the developing economies but also for the developed world. The developed economies of the West could not achieve the rate of growth reached before the global financial crisis struck in 2008. Emerging economies in the East have demonstrated momentum for a couple of decades after the Second World War, but have been experiencing a severe recessionary phase lately. India and China have been growing reasonably since the 1980s, but at a slower rate in the post-financial crisis period, with a number of uncertainties and distress.

Even in economies that have experienced growth in the recent past, the economic benefits have been largely concentrated among the five to ten percent of high-income people in the distribution. As a result, inequality has been growing rapidly. The economic slowdown, coupled with the concentration of capital, has resulted in rising unemployment and under-employment all over the world and forced the unemployed masses to find refuge in the informal and unorganized sectors to somehow eke

out a living. Many leading economists, including Nobel Laureate Joseph Stiglitz, in a couple of his recent books 'Globalization and its Discontents' and 'People Power and Profits', clearly explained this situation as a crisis of capitalism.

Various reports produced by national governments and international agencies (like the IMF and the World Bank) continue to offer hope for a better future but have been recommending further market reforms to overcome the crisis. The desperate need for recovery from the crisis adds pressure on the extent of fossil fuel consumption, the level of carbon produced, and the scale of ecological destruction, further raising the difficulties of sustained capitalism and human survival. This article argues that economic progress cannot be sustained without addressing the damages of social goods driven by global warming and that the roots of the crisis lie in the reckless exploitation of natural resources associated with profit-driven capitalist production.

Private Production, Environmental Exploitation and The Economy

The increasing concentration of carbon dioxide and other greenhouse gases in the atmosphere has been the main reason for global warming. To arrest the runaway warming of the planet, this content must be reduced. For that, it requires (a) discouraging the use of fossil fuels and non-renewable natural resources, (b) encouraging the efforts and investment on renewable energy and resources, and (c) adopting green techniques that emit less carbon. Various initiatives have been taken nationally and internationally in recent decades. However, contemporary evidence reveals that these initiatives produced limited success. So, the question is: How to discourage the use of non-renewable resources and encourage investment in renewable resources.

The problem lies in the production relations and the motive of production in capitalist society. There are at least three factors responsible for global warming: (i) the capitalist mode of production driving individual satisfaction and profit maximization, (ii) the higher environmental cost of renewable resource use, and (iii) the 'prisoners' dilemma' of individual cooperation and international coordination for mitigation and adaptation. The production and exchange of dirty goods takes place in the market of a capitalist society because of the existence of its demand and supply. An individual facing economic difficulties in meeting basic needs cannot afford to spend on consumption and would demand low-cost, dirty goods instead of environment-friendly goods and services. On the other hand, a producer, who is not concerned about the social impact except for his own profit, would not prefer to spend on clean goods and would supply dirty goods. Hence, dirty goods that emit pollutants are being produced and traded.

Capitalist Model of Production

Inequality and unemployment are thriving throughout the world. The capitalist system built on labour exploitation is responsible for such economic polarization. The marginalized people try to survive with low-cost goods, even if these are unhygienic and carbon-intensive. In a capitalist society, labour and capital are assumed to be the two main factors of production, and they complement each other to sustain production but have opposite interests. Capital, as the dominant factor, takes ownership over production. The growth of the economy with such characteristics is driven by two forces—the rate of capital accumulation

and technological change. This can happen only when the capital owners take control of production and try to generate a surplus by depriving the labour from their contribution. Since the income received by workers—the larger section of the population—creates the demand for the produced goods, the higher exploitation reduces their purchasing power and paves the path to a crisis of the system. More importantly, such a system of capitalist exploitation inevitably becomes a factor responsible for sustaining the demand for low-cost and carbon-intensive goods among the large working population. Even those who can afford it would not demand clean goods due to the lack of awareness and social consciousness and more importantly to economize expenses that contribute to the individual capital accumulation.

Moreover, producers would prefer to meet this demand for 'dirty' goods as it does not require investment in green technology and gives them direct profit. In a capitalist society, the basic motive of a production unit is to maximize its own profit, ignoring social considerations. Since the cost of production increases with investment in green technology and therefore reduces profit, producers would not prefer such products unless compelled to do so. The higher price as a result of the increased cost of production reduces the demand for such products in the market and the resulting profit. Therefore, the producer would not prefer green investment unless the state intervenes. The state, intending to protect the interests of the capitalist, may not be keen to impose an additional tax burden. Even if it is imposed, the enforcement is generally weak, and the producer finds ways to bypass it. Hence, the market principle that lies in the capitalist mode of production does not care for the environment.

Resources Exploitation

In addition to the two main factors of production (labour and capital), there exists another set of factors, defined as material inputs in production. It includes (a) energy (e.g. petroleum oil, electricity) and (b) raw materials (e.g., mining resources, minerals, land, water, and forest resources). From an environmental perspective, material inputs have huge implications and can be separated into two types: renewable and non-renewable. A renewable resource is a natural resource that can be replenished over time, making it sustainable for continued use without the risk of permanent depletion. Examples of renewable resources include the sun, wind, water, wood, forest resources, geothermal, and biomass. However, most of these natural resources could only be considered renewable if time and effort is taken to renew and regenerate, such as natural forests, groundwater, etc. This is also true for most precious metals.

Non-renewable resources are those resources that are considered finite because of the extremely long time it takes for nature to create them. They include coal, natural gas, and oil. Unlike renewable resources, once a non-renewable resource is depleted, they are not available and cannot be recovered. The main advantage of non-renewable resources lies in their ready-made usability without investing much time, investment, and effort. Hence, a capitalist would prefer to access them with minimum costs for immediate usage. The infrastructure for their use is in high demand, and a state aiming to grow fast often provides easy access without bothering much about their sustainability. Obviously, they have a greater negative environmental impact than renewable resources, leading to the disruption of the life and livelihood of the present generation.

The heat trapped in the atmosphere by

carbon dioxide gas contributes to the increase of temperature, which causes global climate change. Therefore, the use of nonrenewable resources has two implications: (a) It gradually depletes the resources, which damages the ecology and environment and precludes future generations from the potential benefits of the resources. (b) It emits pollutants, making it responsible for global warming.

Fossil fuels have been used since the late 1880s to produce the energy we use. Renewable resources such as hydropower and wood have been used for a long time. In fact, they were the two main renewable energy resources up to the 1990s. Since then, the production of renewable energy has increasingly come from biomass, geothermal, solar, water, and wind resources. Renewable resources that can replace fossil fuels in the production of energy are a major focus of nations around the world.

The challenges for successful renewable energy production include reliability and expense. The energy obtained from renewable resources puts much less strain on the limited supply of fossil fuels, which are non-renewable resources. As a result, renewable resources have become a focal point of the environmental movement, both politically and economically. The problem with using renewable resources on a large scale is that they are costly and require effort. In most cases, more research is needed to determine how to use them most cost-effectively and to what extent can we make them sustainable. The most pertinent question is, therefore, how to discourage the production units from using non-renewable resources and encourage the application of relatively costly renewable resources.

Would the market principle that works for capital and labour help access the resources? The answer is no. Full private rights cannot be given for the use of non-renewable resources because of non-excludable characteristics and the sustainability threat. They are common resources but still they are often given to large companies, corporations, and multinational enterprises. According to the market rule, the amount of such resources to be supplied depends on their marginal processing costs. Interestingly, the marginal costs of these inputs are low compared to alternative renewables, which drives higher amounts to be depleted and marketed. A higher supply due to a lower price leads to quick depletion and hence excludes future generations from potential use.

If the social cost of such an exclusion is taken into account, the cost of supply would be much higher. However, the private supplier does not count them. Even if a heavy tax is imposed to limit the supply, such a monopoly supplier finds ways to bypass or shift it to the consumer; on the other hand, the user firm would not be willing to pay the social cost because of its private interest and ignores the Paris consensus that proposed a clear agreement of carbon quotas to countries within the permissible limit. Therefore, non-renewable resources are supplied in larger amounts because of their low price, leading to higher carbon emissions. Moreover, a market-driven system cannot force them to invest in alternative renewable sources.

Prisoner's Dilemma or Tragedy of the Commons

The preservation of common and non-renewable resouces requires common efforts and coordination among producers and nations. In a capitalist society, two production units engaged in the same production hardly cooperate for social reasons. Hadin, a renowned environmentalist, defined it as the tragedy of the commons.

Although general concern and awareness for environmental issues have been rising in recent years, firms and countries still continue to pollute and not recycle, harming the planet despite the knowledge that Earth's resources will not last forever. This happens because of the lack of mutual cooperation and coordination between firms and countries. It is a classic example of the *prisoner's dilemma*[*], which describes a clear conflict between individual and collective benefits.

Let us take an example of pollution. In a situation where individuals or groups can benefit from polluting or acting in a way that harms the environment in the short term, even if it leads to long-term negative consequences for everyone, they choose to harm in the short run. This means that countries or industries choose not to reduce emissions because it is cheaper in the short term, even though the long-term costs of pollution are significant. In a capitalist society, nothing could enforce cooperation and trust between parties.

Similarly, when two countries pollute and raise the temperature globally, both need to cooperate or adapt strategies to reduce carbon emissions to effectively curb the temperature. If only one of them does, it may not be effective. Then, the options to cooperate or not cooperate would become a joint decision. If the investment required is more than the benefit from it in the current period and not in the future, both would decide not to cooperate. When all nations involved in climate change negotiations work together and commit to the end goal of reducing emissions, they will always be better off in terms of long-term benefits. However, most negotiations either fall through or commitments are not kept because there are more short-term economic benefits for a country to simply allow other countries to take on the work while not burdening themselves with the changes and regulations necessary to achieve emissions reductions. For this reason, the proposal for a carbon quota has not been implemented. When one country deviates from the agreement, other countries also follow. Again, the lack of social commitment among capitalists is solely responsible for the growing global warming.

Although Alinor Ostrom, the Nobel Laureate, pursued the persistence of local institutions and culture for effective governance of the commons, the grift individualism brought by capitalism with the spread of the market principle have been gradually destroying the existence of such practice and culture, and that paves the path of dire state of commons.

Global Warming and Productivity

Many scholars who believed in the market principle (mainly known as new and neoclassical thinkers) do not recognize the existence of an antagonistic and exploitative relationship between labour and capital, and hence do not subscribe to the predictions of such a crisis in capitalism. However, they recognize the problem of prisoner's dilemma but hold the view that if the state facilitates the market to function properly, the problem could be addressed to a large extent. According to this view, an owner of a firm takes both capital and labour for the production and is forced to pay the labour according to their marginal productivity (defined in terms of extra output produced for an additional factor inclu-

[*]The prisoner's dilemma is a classic game theory scenario that demonstrates why two individuals might not cooperate even if it's in their best interest to do so. It involves two suspects, held separately, who can choose to cooperate (remain silent) or defect (betray the other). The outcome for each depends on the choices of both, creating a dilemma where acting in self-interest leads to a worse outcome for both compared to cooperation.

sion) due to the pressure from rival firms. The quest for a higher surplus in such a competitive market encourages the firm to increase its efficiency and productivity through organizational change and technological improvement. The residual surplus, over and above the total payment given the factors, represents the return or gain from such efficiency change and technology improvement.

So, the sole objective of an economic system is to create a competitive environment that generates productivity improvement, ensuring the dynamics of growth in a capitalist system. In other words, any improvement in technology and organization that not only increases the marginal return of factors (i.e., the wage for labour and rent for capital), but also raises the residual surplus (after making the payment for wage and rent), maintains steady growth and saves the economy from the crisis. The rate of change in this residual surplus is the key driver of economic growth. The question is: Can the state sustain such growth using the market principle by ignoring the consequences of global warming that result from the capitalist mode of production and avoid the crisis? This article argues that the increase in temperature dampens both the marginal return of factors (i.e., wage and rent) and the residue, thus slowing down economic growth and leading to a crisis.

The Theory

The higher the residual surplus, the higher the growth in a capitalist economy. This rate depends on the increase in productivity and efficiency of factors and technology, defined as residual change. For example, if a worker continues to work in the same job, he/she improves skills further, learning from other co-workers or publicly available reading materials and knowledge to efficiently employ the same machine or capital or change the design. This must add value and increase production and residual surplus. In a similar logic, if the production process emits a certain amount of carbon, it damages the health of the workers. The efficiency of the workers would decline with the fall of residual surplus, and the growth would decrease.

When one firm or country pollutes and others do not, then it may contribute to global warming marginally. If many countries are engaged in similar production types, each of them is responsible for emitting pollutants into the environment by the same margin, and the global emissions will be magnified and raise the temperature level. Each individual country will experience an increase in global temperature depending on the global level of pollution. Hence, the impact of temperature would be high on an individual economy, even if it only pollutes marginally to the global environment.

The aggregate emission level is assumed to magnify the impact on global temperature, which damages the ecosystem, deteriorates health conditions, and reduces labour and capital productivity, thus reducing the residual surplus. In other words, productivity that offers residual surplus would decline if the rise in temperature damages any of these three sources. Therefore, production that adversely affects temperature can negatively impact the productivity of physical capital, ecology, and labour. There is growing evidence to show that the increase in temperature dampens productivity with some degree of variation between countries across the globe. If it is true, not only do marginal returns of the factor (i.e., labour and capital) decline, but also the residual surplus (proxied for productivity) falls. In addition, the sensitivity of global warming would vary between countries and occupations depending on

their exposure to climate, location, and resource requirements, which would have differential impacts that would lead to a rise in inequality.

Growth Experiences

Several economic activities and policies designed to contribute to the increase in GDP in a capitalist system are responsible for global warming. These include reliance on fossil fuels for energy production, industrial processes that release greenhouse gases, and deforestation driven by agricultural and commercial interests. Over the past 100 years, global temperatures have generally increased, with the most significant warming occurring in the last 40 years, from the 1980s. It should be noted that the size of GDP (constant 2015 US$) has increased from 26.51 trillion dollars in 1980 to 93.35 trillion dollars in 2023, almost three and a half times higher in 40 years. This has led to a sharp increase in the amount of carbon dioxide from 337.90 ppm in January 1980 to 421.86 ppm in December 2023. Atmospheric carbon dioxide is now 50% higher than before the Industrial Revolution. The amount of CO_2 in the atmosphere has increased by more than 20% in the last 45 years.

The structure of the global economy, which prioritizes economic growth without sufficient consideration of environmental impacts, plays a significant role. During the 17th and 18th centuries, industrialization was concentrated in Western countries and carbon concentration was relatively low. Due to the pursuit of capitalist development that exploits labour and, thereby, reduces purchasing power and generates market crisis for increased production, Western countries started to face the crisis of the market to sell their products and absorb the working population, which led them to find markets outside the nation and establish colonies in Asia, Africa and Latin America. The crisis was so acute that colonial expansion could not solve their problems, forcing them to participate in the First World War. Even then, the crisis continued and was severely exposed in the Great Depression in the 1930s, followed by the Second World War. In parallel, the crisis encouraged people to find an alternative economic system and led to the struggle for socialism, which promised a greater presence of the state in delivering production and distribution with social equity and concerns where the market fails. Russia embraced socialism, which encouraged the independence movement in colonial states. The presence of the socialist movement compelled the state to participate in economic activities to a significant extent in the capitalist world. As the presence of the socialist state declined, privatization and globalization started to thrive with the fall of state intervention from 1980 onward.

Interestingly, this is the period when the level of carbon concentration has started to explode. Most countries in the world pursued privatization and globalization strategies that relied on market principles to accelerate growth. The international agencies prescribe that developing countries that gained independence after WWII undertake reform to overcome their development challenges. The reform includes measures to accelerate international trade and capital flows with minimal state intervention. But such rampant privatization that drives the private motive for capital accumulation might have contributed to residual surplus required for economic growth to some extent, but at the cost of the environment.

Empirical research has been growing to estimate the impact of global warming. Under normal business conditions, the temperature can rise to 4°C. To capture global warming, two alternative variables

are treated to capture the impact—one using the annual temperature for the change and another using the variation for the fluctuation of extreme events. An increase in temperature of 1°C in both developed and developing countries has been found to lead to a drop in economic growth of 1.3 to 4% annually, depending on their climate exposure, geographical region, economic activities and level of development. Some literature found a direct impact of climate change on GDP and productivity growth by estimating the social cost of carbon. This account represents a dollar estimate of the economic damage caused by emitting an additional ton of CO_2 into the atmosphere. According to a study on the evolution of climate in *Nature*, in the last 10 years, estimates of the social cost of carbon have increased from US$9 per tCO_2 to US$40 per tCO_2 for a high discount rate and from US$122 per tCO_2 to US$525 per tCO_2 for a low discount rate. The discount rate is the interest rate used to determine the present value of future cash flows. It represents the time value of money, reflecting the idea that a dollar today is worth more than a dollar in the future. The cost could be higher if an economy does not necessarily contribute much to the reduction of carbon content globally.

For example, India emits less carbon compared to the US and China, but the social cost of carbon emissions was calculated to be around $90 per tonne of CO_2 in India, which means that each additional tonne of CO_2 will cost a loss of Indian wealth of $90. The economic costs of CO_2 emissions are estimated to be $50 and $26 per tonne for the US and China, respectively. Therefore, the social cost of carbon (SCC) estimated by Integrated Assessment Models (IAMs) has been found to have a negative effect on growth from 0.7% to 5% across nations. Other studies have further predicted that a 4°C temperature rise could lead to a 40% reduction in global GDP by 2100. Even a 2°C rise could result in a 16% decline in global GDP per capita.

The growing industrial pollution and consumption of fossil fuels have resulted in a rapid rise in global temperature and emissions, damaging ecosystems and productivity, and the resulting growth. The rise in greenhouse gas (GHG) stocks significantly contributes to global warming. Weather anomalies caused by climate change have caused further devastation around the world. Extreme weather events caused 11,778 reported disasters between 1970 and 2021, with more than 2 million deaths and US 4.3 trillion dollars in economic losses. Extreme weather events, for example droughts, heat waves, cold waves, storms, flooding, hurricanes, and wildfires, are significantly intensified by climate change. The less developed and developing economies are especially vulnerable to the economic and social consequences of these climate transformations due to geographical factors and levels of development, which restrict their adaptive capacity. Therefore, such weather deterioration is more harmful to emerging markets facing social and economic challenges in fostering productivity growth, which determines economic growth.

Labour productivity, a significant component of productivity growth, is directly affected by temperature. High temperatures have been shown to reduce worker efficiency, increase fatigue, and increase error rates. These effects are more pronounced in industries that require outdoor work or have less climate-controlled environments, such as agriculture and construction. Excess heat can cause stress, reducing the number of hours worked and the intensity of labour. In addition, rising temperatures affect capital productivity in

several ways. For example, engines and electronic devices can overheat, leading to breakdowns or requiring more frequent maintenance. Extreme temperatures can accelerate infrastructure wear and tear, increase maintenance costs, and reduce the lifespan of capital assets. Higher temperatures increase the demand for cooling, increase energy costs, and reduce the net productivity of energy-dependent capital.

In addition, productivity damage in poor and less developed countries is found to be much more severe than in developed countries due to their dependence on labour-intensive activities and agriculture. However, not all countries find the same order of damage. Countries located in moderate-temperature zones face lower losses. Because low- and middle-income countries rely more heavily on agriculture and have less ability to adjust to these temperatures, the harm from higher temperatures is expected to be particularly severe in these countries. They often lack the financial resources and institutional frameworks necessary to mitigate and adapt to the impacts of climate change effectively.

Several potential channels through which climate change can affect these economies include reduced agricultural production and higher food prices, leading to inflationary pressures, reduced disposable income, and increased food insecurity. Rising temperatures and the increased frequency of extreme weather events can lead to health crises, increasing the burden on public health systems, and reducing labour productivity. Extreme weather events such as hurricanes, floods, and droughts can cause significant damage to the infrastructure, leading to substantial reconstruction costs and disrupting economic activities. Changes in precipitation patterns and increased evaporation rates can lead to water scarcity, affecting both agriculture and industrial activities, and potentially leading to conflicts over water resources. Climate-induced displacement and migration can strain urban centres, leading to social unrest and increased demand for public services. Furthermore, the increased risk and uncertainty associated with climate change can lead to greater volatility in financial markets. Investors may demand higher risk premiums, increasing the cost of capital for developing economies.

During times of financial instability, developing economies experience significant economic disruptions, including depreciating exchange rates, domestic recessions, widening sovereign spreads for investment, increased external debt, and balance-of-payments difficulties. As climate change accelerates, the frequency of events that disrupt the financial system is expected to increase due to their limited financial capacity. Climate-induced physical disasters destroy wealth held in asset portfolios, while mitigation strategies and changing investment patterns increase transitional risks due to the strong link between the financial system and carbon-intensive industries. In addition, climate change is projected to fundamentally reduce the growth potential through various channels, such as the destruction of capital stocks, a reduction in labour productivity, and a decrease in agricultural production. This, in turn, affects the solvency of firms and households, damages the balance sheets of banks, and impedes loan issuance. Furthermore, climate change increases uncertainty, inhibits entrepreneurship, and disrupts global supply chains, which can interrupt just-in-time production patterns, leading to a sustained crisis.

Development Experiences

Climate change exacerbates inequality, as its burdens disproportionately affect poorer

households and countries, making the costs of mitigation and adaptation measures prohibitively high for them. In the previous section, it has been discussed that poorer countries are facing greater damage than developed nations, indicating that global warming serves as a catalyst for increasing regional inequalities. During the last two decades, wealth inequality has been driven by various factors, including economic growth, globalization, demographic changes, financial development, and government policies. Global warming, a critical yet often overlooked determinant, significantly impacts socio-economic equality. The growing research on global warming reveals that it worsens inequalities between and within countries. Rural areas, typically poorer, suffer more severe impacts than urban areas. Within these regions, the most vulnerable populations—those with the least resources to enable them to adopt—are the hardest hit. Climatic shocks disproportionately displace poorer individuals who depend more on climate-sensitive activities and lack resources and robust coping mechanisms.

Natural disasters increase income inequality in the short term, but this effect diminishes over a longer period. In contrast, catastrophic natural disasters are argued to reduce inequality in both the short and long term, primarily by significantly impacting wealthier households. Moreover, it shows that global warming has significantly widened economic inequality between countries. Their findings reveal that global warming has reduced per capita GDP by 17–31% in the poorest four deciles, significantly contributing to the wealth gap that is 25% greater than it would be in a world without global warming. Scholars extend this analysis to a subnational level, showing that a 1°C rise in temperature results in 0.8% and 1.4% increases in the Gini and Theil indices, respectively.

Global warming can directly damage physical assets, such as housing, infrastructure, and agricultural land, or indirectly impact household incomes by forcing the sale of assets to smooth consumption. In this context, poor people are often hit relatively harder. For example, wealthier households often have better access to formal insurance and safe arrangements or credit facilities, allowing them to recover more quickly, while poorer households may face greater barriers to rebuilding their asset base.

By analyzing climate shocks in less developed countries, such as Ethiopia and Honduras, studies show that while all households experience immediate income drops due to climate-induced factors such as crop failures and increased medical expenses, poorer households struggle to rebuild their asset base over the medium to long term. In contrast, wealthier households are better able to protect or accumulate assets, either through market mechanisms or by leveraging social networks.

Global warming profoundly impacts human well-being, with differential impacts between men and women due to their differential adaptations and exposure to shocks and vulnerability, more so in an unequal society. Empirical studies indicate that climate shocks have led to declines in women's economic and social rights due to the prevalence of greater discrimination in developing countries.

In addition, a significant disparity can be seen in the impact of ambient temperatures on mortality in human populations. Analyzing district-level weather and mortality data from 1957 to 2000 in India, a study revealed that hot days substantially increase mortality in rural areas, driven by adverse effects on agriculture and productivity. Urban populations exhibit mortality

responses similar to those in India and the United States. Further, analyzing data from 1971 to 2000, the scholar identified strong causal links between weather shocks and crime, primarily influenced by agricultural income shocks.

Negative rainfall and positive temperature shocks during the main agricultural season lead in a notable way to an increase in property crime rates. The findings highlight more substantial effects of weather shocks on property crimes than non-property crimes, aligning with economic models emphasizing income mechanisms. The study also noted a consistent relationship between crime and weather over time, with negative rainfall consistently associated with a 5% increase in crime and temperature shocks remaining stable at about 4%. The expansion of irrigation does not appear to mitigate these impacts, suggesting the enduring vulnerability of a segment of society susceptible to weather-induced income shocks and prone to criminal adaptation.

Concluding Remarks

Global warming and its resultant economic losses are rooted in the capitalist mode of production that allows for sustained carbon emissions and continuous depletion of non-renewable resources. Typical uses of fossil fuels increase the carbon content of the atmosphere, which causes efficiency losses in workers, capital, and ecology and dampens productivity and economic growth. The damage is more pronounced in less developed and tropical countries, agricultural activities, and poor individuals and women due to their dependence on manual work, which has contributed to the trend of increasing inequality during the last couple of decades.

Countries have taken various measures and have promised to achieve the target of zero carbon emissions, but have not shown any sign of recovery so far. If this continues, the global temperature can rise up to 4°C, and economic growth can fall to 25% by the end of this century. The big question remains: Can the exploitation of fossil fuels and non-renewable resources be stopped, and can the zero-carbon emission target be achieved under the capitalist system by making any cosmetic changes in the adaptive strategies? If not, what would be the alternative? The answer to this question would decide the destiny of human civilization. □

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