Carbon Emission Peaking During Economic Crises: Structural Shifts in Industrialized Nations

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Abstract. This research report analyzes the dynamics of carbon emissions during economic crises, focusing on structural changes in industrialized countries. The study covers periods of economic crisis and pays attention to changes in carbon-emitting industries. It is assumed that during periods of crisis, structural shifts occur, as a result of which carbon emissions may temporarily decline. The factors influencing this process are analyzed, and its impact on the overall level of carbon emissions in the long term is assessed. The findings help to understand how economic crises affect carbon emissions and what policy measures can be taken to manage these emissions in the future.

1 Introduction

In recent times, many developing nations have faced a shared challenge: environmental deterioration due to the unregulated release of CO2 into the atmosphere [1]. The surge in industrial activities has led to a rise in carbon emissions, driven by increasing industrialization and urbanization. Consequently, this surge has significantly heightened the global concentration of anthropogenic greenhouse gases like CO2, resulting in alarming phenomena such as global warming and climate change.

Climate change has caused a decline in global agricultural output due to factors like reduced rainfall, shifting seasons, and rising temperatures. Many regions are experiencing droughts, rendering vast areas unsuitable for farming. Additionally, fluctuating temperatures and precipitation patterns are expected to worsen soil and water degradation. However, adaptive measures hold promise in mitigating these effects, with land use and management exerting a greater influence on soil health than climate change itself. Even if all human-induced emissions were to cease suddenly, climate conditions would continue to change. The current levels of pollution and unchecked greenhouse gas emissions could worsen global warming, ocean acidification, desertification, and erratic weather patterns. Immediate consequences of climate change include food insecurity, rising sea levels, intensified storms, health issues, migration pressures, and economic losses.

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As knowledge about mitigating CO2 emissions grows, there is a pressing need to incorporate recent advancements and future prospects into environmental efforts to promote cleanliness [3]. Moreover, concerted efforts are required to address the root causes of anthropogenic climate change and mitigate its severe effects. Environmental degradation, as defined by Ahmed et al. [6], refers to disturbances in natural ecosystems that hinder the survival of various life forms. Alternatively, the United Nations' International Strategy for Disaster Reduction defines it as the environment's diminishing capacity to meet environmental, social, and ecological needs [4].

Environmental degradation encompasses the depletion of environmental resources such as air, water, and soil; the destruction of ecosystems; wildlife extinction; and pollution harmful to the ecosystem. It is recognized as one of the foremost global threats [9]. Environmental degradation exists in various forms, from the destruction of natural habitats to resource depletion and environmental deterioration. Efforts have been made to combat this issue through conservation and resource management, but it persists.

For example, the ongoing Amazon rainforest fires, which affect 60% of all tropical forests, pose a significant threat to the global environment [5]. Additionally, widespread deforestation contributes to environmental degradation by depleting oxygen levels, disrupting CO2 absorption, and generating excessive waste. Moreover, deforestation leads to soil degradation, reducing soil fertility and hindering agricultural productivity. This chapter aims to address environmental issues stemming from rising CO2 levels in the atmosphere.

The combustion of fossil fuels, notably coal, is the primary source of CO2 emissions. Coal combustion, particularly for power generation, is the largest contributor to atmospheric CO2 emissions. Atmospheric CO2 levels are projected to rise continuously if CO2 emissions are not addressed. For instance, the average atmospheric CO2 concentration in 2019 was 414.7ppm, marking a 45% increase from levels recorded between 1980 and 1990. Furthermore, human-induced global CO2 emissions have surged by over 400% since 1950. Meeting the goals of the Paris Agreement requires annually capturing and storing at least 1 gigaton (Gt) of CO2 until 2030 [3].

2 Research methodology

Furthermore, there is a widespread acknowledgment of the substantial contribution of coal-fired power plants and other fossil fuel-based facilities to the global emission of CO2. For instance, a standard 500MW power plant has the capacity to release millions of tons of CO2 into the atmosphere annually [4].

Emissions of methane, a potent greenhouse gas, stem from various sources including agricultural activities such as cattle breeding, coal mining, oil and gas production and distribution, biomass combustion, and municipal landfills. Without immediate action in these sectors, methane emissions are projected to rise beyond 2030. The energy sector, encompassing coal mining, natural gas systems, oil systems, and combustion systems, stands out as the largest contributor to methane emissions, accounting for approximately 303 tons emitted in 2009.

Agricultural activities, particularly cattle breeding, and waste management, mainly from landfills, are significant sources contributing about 216 tons of methane to the atmosphere. Methane is a potent greenhouse gas with a global warming potential estimated to be 28–36 times higher than CO2 over the past century, making it the second most significant anthropogenic greenhouse gas emitted into the atmosphere [2]. Therefore, understanding methane emissions is crucial for evaluating the impact of the biogas industry on climate change. Moreover, significant methane emissions occur during biogas combustion, with a notable portion originating from biomass conservation and management waste.

Studies, such as one conducted by Poeschl et al., have extensively discussed methane emissions, revealing rates consistently below 5 g kg-1 across various cases. Proper processing and management of digestive products, particularly cattle manure, can significantly reduce methane emissions. For instance, implementing non-decomposing feeding strategies for animals in agriculture could potentially reduce global methane emissions by 20% before 2030. Additionally, employing periodic aeration of permanently flooded rice fields could lead to a reduction of methane emissions by over 30%.

Emissions from coal mining, as well as the oil and gas sector, could be slashed by over 65% by preventing gas leaks during transportation, distribution, recovery, and utilization at the production stage [3]. These measures are essential for mitigating methane emissions and curbing their detrimental impact on the environment.

3 Results and Discussions

CO2 is released into the atmosphere through various human activities, primarily the burning of fossil fuels like coal, natural gas, and oils, as well as the combustion of solid waste, trees, and other organic materials. Additionally, certain industrial processes, such as cement production, can also generate CO2 emissions . The issue of CO2 emissions, global warming, and subsequent climate change demands urgent scientific attention, prompting the imperative for reducing CO2 emissions across all human activities, notably in power generation. Research efforts have been substantial in mitigating anthropogenic CO2 release into the atmosphere [3]. Various techniques like adsorption, absorption, and membrane separation have been proposed and tested for CO2 capture, yet these methods are resource-intensive, making implementation costly for many nations. However, employing process integration techniques, such as heat and mass exchanger network synthesis, can potentially alleviate the energy and material demands of CO2 capture methods. It's noted that CO2 emissions do not directly cause climate change but rather deplete the ozone layer, leading to global warming and subsequent climate shifts.

Human activities like power generation, cement production, and transportation significantly contribute to greenhouse gas emissions and global warming.

It’s suggests that incorporating CO2 capture mechanisms into existing power plants, particularly through heat and mass exchanger network integration, can be feasible and cost-effective. Nevertheless, international treaties aimed at reducing greenhouse gas emissions face challenges like withdrawal by some developed nations, insufficient memberships for effective implementation, and incomplete adherence by participating countries [4-5]. Hence, there's a pressing need to explore alternative strategies to safeguard the environment and avert future environmental crises stemming from escalating CO2 emissions due to human activities (fig.1).

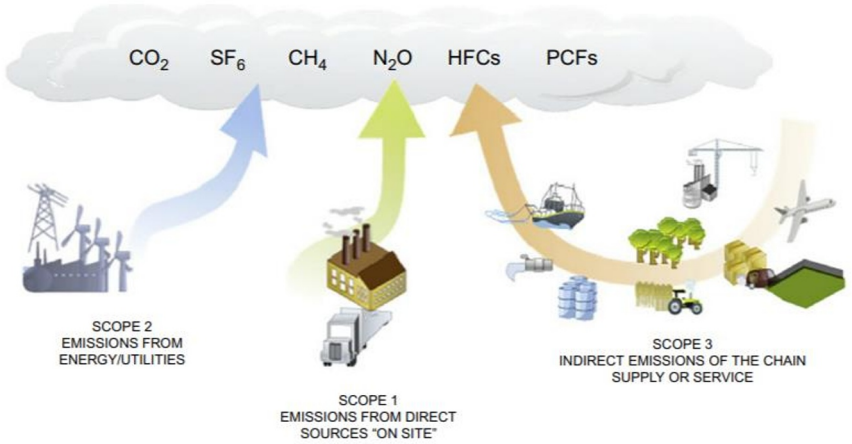

Fig. 1. Classified sources of greenhouse gas emission

The analysis of countries experiencing peak-and-decline emissions trajectories uncovers two primary factors influencing the timing of emissions peaks. Firstly, following economic crises, there was a notable decline in post-crisis GDP growth, resulting in a slower rate of emissions growth compared to pre-crisis levels. Although economic growth eventually resumed across all countries, it did so at a reduced pace, leading to a moderation in emissions growth [6-7]. Exceptions to this trend were observed in countries such as Lithuania, Latvia, Greece, and Italy, where prolonged recessions post-crisis resulted in slight decreases in emissions.

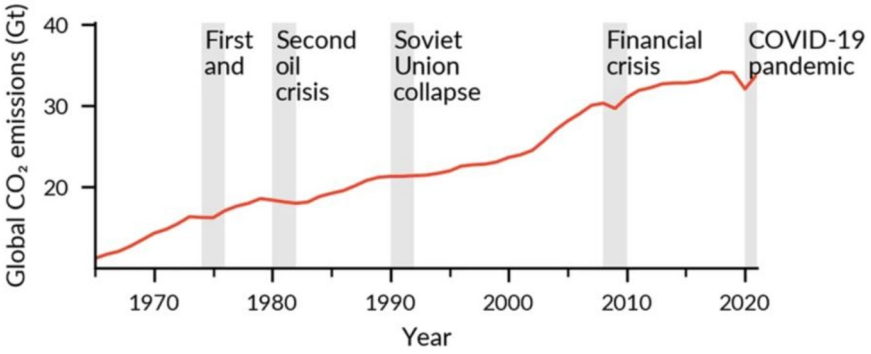

Fig. 2. Global CO2 emissions from fossil fuel combustion. The grey shades represent the five biggest economic crises in 1965–2021

Secondly, structural changes towards lower emission levels were evident in these countries, with combined energy and carbon intensities experiencing negative growth rates post-peak crisis [8]. This effect intensified after the crises, leading to accelerated reductions in energy and carbon intensities in most cases. Even in instances where emissions trends were increasing before the crises, a transition to decreasing emissions occurred post-crisis. Overall, the intensified structural changes, combined with lower GDP growth, account for the emissions peaks and sustained state of absolute decoupling observed in these countries.

This paper offers significant contributions to the ecological economics and climate policy literature in two main areas [9]. Firstly, it expands upon existing research by investigating how major economic crises impact CO2 emissions peaks in OECD and G20 economies, thereby extending our understanding of the drivers behind declining CO2

emissions. Secondly, it addresses the limited but growing evaluations of the effects of crises on decarbonization efforts, specifically focusing on the impacts on structural change within economies (Fig.2).

The study highlights that economic crises have induced structural changes in many major economies, resulting in CO2 emissions peaks. This suggests that previous research focusing solely on global trends may have underestimated the influence of crises on decarbonization [10].

Understanding the effects of economic and energy crises on decarbonization is crucial for developing effective climate mitigation strategies, especially those aiming for carbon neutrality by 2050. While some countries reached emissions peaks due to proactive policies prior to crises, others intensified their support for decarbonization during periods of economic instability, often through policy reforms and green Keynesianism programs. Severe recessions also facilitated the adoption of less carbon-emitting technologies and economic activities.

The findings contribute to the ongoing debate between green growth and degrowth. While achieving absolute decoupling is possible, it requires moderate GDP growth to ensure emissions reduction, and sustained efforts over time are necessary for reaching zero emissions [11]. However, the impacts of crises on decarbonization efforts are not uniformly positive, as some countries may revert to more carbon-intensive economic models during recovery phases.

To address this, proactive policies promoting energy efficiency and clean energy should be implemented before crises occur to support cleaner industries during recovery periods. Although emissions peaks may not always align with economic downturns, crises can accelerate the peaking process, thereby facilitating earlier attainment of emission reduction goals.

4 Conclusions

While our study offers valuable insights, it also comes with several limitations that call for further exploration. Firstly, we focused solely on production-based emissions, neglecting the potential impact of economic crises on consumption patterns and emissions. Future research should investigate how economic downturns affect demand and consumption-related emissions. Secondly, our study did not delve into the specific factors driving emissions peaks in different countries or the precise effects on their economic structures and energy systems. Further in-depth, country-specific case studies are necessary to uncover the underlying causes of each peak or non-peak scenario.

Moreover, it is premature to fully gauge the effects of the Covid-19 pandemic and the ongoing energy and economic crisis resulting from the war in Ukraine on emissions peaks and long-term structural change. While the pandemic led to a significant GDP drop, the swift recovery and global policy responses may mitigate the long-term impacts of creative destruction. However, disruptions in global supply chains and a potential shift towards re-localizing production could alter previous trends in globalization and emissions. Politically, the response to the Covid-19 crisis differs from past crises, with many countries prioritizing green recovery packages to hasten technological advancements and decarbonization endeavors. Lastly, the war in Ukraine has caused disruptions in the global energy system akin to the oil crises of the 1970s, prompting strategic decisions by governments and firms that will influence efforts towards achieving net-zero emissions by 2050. Further research is imperative to understand the ramifications of these crises on emissions trajectories and decarbonization initiatives.

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