

Review Article

Theoretical Insights into the Economics of Climate Change and Environmental Policy

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Abstract

Climate change represents one of the most pressing challenges of the 21st century, with far-reaching consequences for global economic stability, ecological systems, and social equity. This review article conducts a rigorous theoretical exploration of the economics of climate change, analyzing the interplay between market failures, environmental externalities, and policy interventions designed to mitigate greenhouse gas (GHG) emissions. By synthesizing insights from environmental economics, game theory, and public policy, the study evaluates the efficacy of carbon pricing mechanisms (such as carbon taxes and cap-and-trade systems), regulatory instruments, and innovation-driven strategies in fostering a sustainable transition. A central focus of this research is the translation of economic theory into actionable policy solutions, addressing the global and intergenerational nature of climate change. The study critically examines how carbon pricing can internalize the social cost of emissions while balancing efficiency and equity concerns. Additionally, it highlights the pivotal role of technological innovation—supported by subsidies, R&D investments, and directed technical change—in decoupling economic growth from carbon dependency. Empirical evidence from case studies, such as the EU Emissions Trading System (EU ETS) and British Columbia's carbon tax, underscores both the successes and limitations of existing policies. The analysis also emphasizes the need for equitable climate action, given the disproportionate burden faced by developing nations and vulnerable populations. Financial and technological transfers are identified as essential components of a just transition. Furthermore, the study explores the challenges of international cooperation through game-theoretic models, revealing the collective action dilemmas inherent in climate agreements like the Paris Accord. Strengthened enforcement mechanisms and adaptive governance frameworks are proposed to enhance compliance and ambition. Ultimately, this review advocates for hybrid policy approaches that integrate carbon pricing, innovation incentives, and equity considerations. By bridging economic theory with real-world policy design, the study contributes to the development of resilient, low-carbon strategies that align environmental sustainability with inclusive economic growth.

Keywords

Climate Change, Carbon Pricing, Environmental Policy, Market Failures, International Cooperation

1. Introduction

Climate change has emerged as one of the most significant global challenges of our time, with profound implications for

economic systems, environmental stability, and human well-being. The Intergovernmental Panel on Climate Change

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has emphasized that human activities, particularly the combustion of fossil fuels and land-use changes, are the primary drivers of rising greenhouse gas (GHG) concentrations, leading to global warming and its associated impacts [1]. These impacts include more frequent and severe weather events, rising sea levels, biodiversity loss, and disruptions to agricultural systems, all of which pose substantial risks to economic growth and development.

The economics of climate change revolves around understanding the costs of inaction, the benefits of mitigation and adaptation, and the trade-offs involved in transitioning to a low-carbon economy. Recent studies highlight the growing economic burden of climate-related disasters, with global losses estimated at over \$300 billion annually [2]. At the same time, the transition to renewable energy and sustainable practices presents significant opportunities for innovation, job creation, and long-term economic resilience. However, achieving these benefits requires addressing market failures, such as the under-pricing of carbon emissions and the lack of incentives for green technologies, which hinder progress toward climate goals.

Environmental policies, including carbon pricing, cap-and-trade systems, and subsidies for renewable energy, are critical tools for internalizing the social cost of carbon and aligning economic incentives with environmental objectives. Recent research underscores the effectiveness of carbon pricing in reducing emissions while generating revenue for green investments [3]. However, the design and implementation of these policies must consider equity concerns, as the costs of climate action and the impacts of climate change are often disproportionately borne by vulnerable populations. Furthermore, the role of technological innovation and behavioral change in driving sustainable transitions cannot be overstated, as highlighted by studies on the rapid decline in renewable energy costs and the potential for digital technologies to enhance energy efficiency [4].

This study aims to provide theoretical and practical insights into the economics of climate change and environmental policy, drawing on recent literature and empirical evidence. By examining the interplay between economic theory, policy design, and real-world outcomes, the research seeks to contribute to the development of strategies that balance economic growth with environmental sustainability.

2. Literature Review

2.1. Theoretical Frameworks

2.1.1. Definition of Climate Change and Environmental Policy

Climate change refers to long-term shifts in global or regional climate patterns, primarily driven by human activities such as burning fossil fuels, deforestation, and industrial processes, which increase greenhouse gas (GHG) concentra-

tions in the atmosphere. According to the IPCC [1], climate change is characterized by rising global temperatures, melting ice caps, sea-level rise, and more frequent extreme weather events.

Environmental policy encompasses laws, regulations, and initiatives designed to mitigate environmental degradation and promote sustainability. In the context of climate change, it includes measures like carbon pricing, renewable energy incentives, and emission reduction targets aimed at addressing GHG emissions and adapting to climate impacts [2].

2.1.2. The Nexus of Economics of Climate Change and Environmental Policy

The intersection of economics, climate change, and environmental policy forms a critical nexus for addressing global challenges. Key elements include:

Market Failures and Externalities: Climate change is a result of market failures, where the social costs of GHG emissions are not accounted for in market transactions. Environmental policies, such as carbon pricing, aim to internalize these externalities [5].

Cost-Benefit Analysis: Tools like the social cost of carbon (SCC) guide policymakers in setting emission reduction targets and designing cost-effective interventions [1].

To accelerate green innovation, policymakers should implement renewable energy subsidies and increase R&D funding [6].

Equity and Distributional Impacts: Policies must address the disproportionate impacts of climate change on vulnerable populations [7].

Global Cooperation: Climate change is a global public good, requiring collective action and international agreements like the Paris Agreement [8].

2.2. Empirical Literature

2.2.1. Empirical Evidence on Climate Policy Effectiveness

Empirical studies provide robust evidence on the effectiveness of climate policies, particularly carbon pricing mechanisms, in reducing greenhouse gas (GHG) emissions. Martin et al. [9] found that the European Union Emissions Trading System (EU ETS) reduced emissions in the power sector by 10% between 2005 and 2020, demonstrating the efficacy of cap-and-trade systems. However, the study also identified challenges such as price volatility and over-allocation of permits in the initial phases, which underscore the importance of robust policy design and adaptive governance.

Similarly, Green [10] reported a 10% reduction in emissions in British Columbia following the introduction of a carbon tax in 2008, with no significant adverse effects on economic growth. This supports the theoretical argument that carbon pricing can achieve emission reductions without

compromising economic performance. However, the implementation of carbon pricing in developing economies faces significant barriers, including political resistance and limited institutional capacity [7]. These challenges highlight the need for tailored approaches that account for the socio-economic and political contexts of low- and middle-income countries.

2.2.2. Long-Term Benefits of Early Climate Action

Subsequent empirical analyses have confirmed the validity of Stern's low discount rate methodology, quantitatively demonstrating that the net present value of early climate mitigation substantially exceeds near-term implementation costs when evaluated over appropriate time horizons. For instance, investments in renewable energy have not only reduced emissions but also driven significant cost reductions and job creation [11]. Falkner [12] analyzed the implementation of Nationally Determined Contributions (NDCs) under the Paris Agreement and found that while the agreement has increased global ambition, many countries are not on track to meet their targets. This underscores the need for stronger enforcement mechanisms and enhanced international cooperation.

2.2.3. Role of Innovation and Technology

Technological innovation has played a pivotal role in decoupling economic growth from emissions. According to IRENA [4], the cost of solar photovoltaic (PV) electricity fell by 85% between 2010 and 2022, driven by policy support and advancements in technology. This aligns with the theoretical argument that innovation is critical for achieving sustainable transitions. Dechezleprêtre et al. [13] further demonstrated that government subsidies for clean energy research and development (R&D) have significantly increased patent filings in renewable technologies, particularly in wind and solar energy. These findings highlight the importance of policy-driven innovation in accelerating the transition to a low-carbon economy.

2.2.4. Equity and Distributional Impacts

Equity considerations are central to the design and implementation of climate policies. Studies on carbon tax implementations in Canada and Sweden show that revenue recycling through lump-sum rebates or social programs can mitigate regressive impacts on low-income households [10]. However, significant disparities remain in global climate finance. Buchner et al. [14] found that climate finance flows reached 650 billion in 2022, far below the estimated 650 billion in 2022, far below the estimated 4 trillion annually needed to meet Paris Agreement targets. Developing countries continue to face substantial funding gaps, emphasizing the need for increased financial and technological support from developed nations.

3. Methodology of the Study

This study employs a theoretical approach, drawing on existing economic models and frameworks to analyze the economics of climate change and environmental policy. The methodology involves:

Theoretical Modeling: Using established models such as the DICE model and game-theoretic frameworks to explore the dynamics of climate change mitigation.

Comparative Analysis: Comparing the effectiveness of different policy instruments, including carbon taxes, cap-and-trade systems, and renewable energy subsidies.

Case Studies: Examining real-world applications of climate policies in various countries to assess their theoretical underpinnings and practical outcomes.

Synthesis of Literature: Integrating insights from recent studies to identify gaps and propose new directions for research.

4. Results and Discussion

The theoretical analysis reveals several key insights into the economics of climate change and environmental policy:

Carbon Pricing: Carbon taxes and cap-and-trade systems are effective tools for internalizing the externalities of greenhouse gas emissions. However, their success depends on careful design, including considerations of price stability and equity. For example, the European Union's Emissions Trading System (EU ETS) has demonstrated the potential of cap-and-trade systems, but challenges remain in addressing price volatility [15].

Innovation and Technology: Policies that incentivize clean energy innovation are essential for long-term sustainability. The theoretical framework of directed technical change [16] highlights the importance of subsidies for renewable energy research and development.

International Cooperation: Climate change is a global problem that requires coordinated action. The Paris Agreement [17] represents a significant step forward, but theoretical models suggest that stronger enforcement mechanisms are needed to ensure compliance [8].

Equity Considerations: Climate policies must address the disproportionate impacts of climate change on vulnerable populations and developing countries. Theoretical models emphasize the importance of financial transfers and technology transfer mechanisms to promote equity [18].

5. Conclusions and Recommendations

This study highlights the indispensable role of economic principles in addressing the complex and multifaceted challenge of climate change. The theoretical analysis reveals that carbon pricing mechanisms, such as carbon taxes and cap-and-trade systems, are effective tools for internalizing the

externalities of greenhouse gas (GHG) emissions. However, their success depends on equitable and politically feasible designs to ensure broad acceptance and effectiveness.

Policies that incentivize clean energy innovation are critical for achieving long-term sustainability. The rapid decline in renewable energy costs and advancements in technologies like solar and wind energy underscore the transformative potential of innovation-driven strategies.

International cooperation remains paramount, as climate change is a global issue requiring coordinated action. While the Paris Agreement [17] marks significant progress, stronger enforcement mechanisms and enhanced collaboration are needed to ensure compliance and equitable burden-sharing among nations.

Finally, equity and inclusivity must be central to climate policy design. Addressing the disproportionate impacts of climate change on vulnerable populations and developing countries requires equitable frameworks, including financial transfers and technology-sharing mechanisms, to ensure fair distribution of costs and benefits.

In conclusion, integrating economic theory with practical policy solutions offers a pathway to balancing economic growth with environmental sustainability. By prioritizing innovation, equity, and global cooperation, policymakers can design effective strategies to mitigate climate change and build a resilient, low-carbon future.

In light of these findings, the study recommends the adoption of hybrid policy approaches that combine carbon pricing with subsidies for renewable energy and research and development. Additionally, international institutions must strengthen mechanisms for technology transfer and financial support to developing countries. Future research should focus on the behavioral aspects of climate policy and the role of adaptive governance in addressing uncertainties and evolving challenges.

By integrating economic theory with practical policy solutions, this study contributes to the development of strategies that balance economic growth with environmental sustainability, paving the way for a resilient and low-carbon future.

Abbreviations

IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
OECD	Organization for Economic Co-operation and Development
R&D	Research and Development
UNFCCC	United Nations Framework Convention on Climate Change

Author Contributions

Tesfay Gebrehiwet Abrha is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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