Policies Against Climate Risks and Behavioral Constraints—An Overview and Evaluation

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Abstract

In some academic and policy circles, carbon pricing, generally in the form of Cap & Trade or carbon taxes (see Metcalf and Stock (2020)), is often seen as a key strategy for tackling climate change and its associated risks. Others support directed technical change and direct investments in cleaner energy sources (see Acemoglu et al. (2012) and Aghion et al. (2022)). One can design theoretical and model-guided strategies and efficient or optimal paths to decarbonization of the economy. Politically, however, one of the most important issues is that significant behavioral constraints exist in actual policymaking. This paper provides an overview and survey of the strengths and weaknesses of either side of the decarbonization strategy and the role of behavioral drivers toward a low-carbon economy, assessed from the macro- and microeconomic perspectives.

Keywords: Climate risks, Behavioral constraints, Carbon pricing, Limit pricing

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1 Introduction

Climate change and climate-related risks have become more significant and complex than any other environmental challenge (Roy et al., 2024). Given the critical importance of addressing climate change, efforts have been concentrated on reducing greenhouse gas emissions, particularly CO2. These efforts range from mitigation policies – focused on reducing emissions to slow global warming – to adaptation policies – aimed at adjusting systems and practices to minimize the damage caused by climate change. Additionally, resilience and adaptation policies seek to enhance the ability of communities and ecosystems to recover from climate-related shocks, such as extreme weather events.

However, even well-designed policies may fail or underperform if they do not account for policy components related to behavioral constraints that influence decision-making. These policies refer to strategies and interventions aimed at addressing climate change and its associated risks, while also taking into account the various factors that shape how individuals and organizations respond to these challenges. These barriers and policies can be assessed at both macro and micro levels. By understanding and addressing behavioral constraints and their effects at these levels, policymakers can design improved interventions that lead to more effective actions on climate change.

In some academic circles, carbon pricing is often seen as a key strategy for tackling climate change and its associated risks by reducing carbon emissions. However, market-oriented optimal control models like IAM, DICE, or DSGE aim to study the optimal transition path to a low-carbon economy but often overlook actual behavioral drivers that complicate the effectiveness of such strategies. These drivers include inertia induced by behavioral stickiness, technological lock-ins, irreversibilities, and leakages, as well as non-cooperative behaviors by countries and companies, alongside the role of limited information among agents and the unavailability of substitutes. These constraints are likely to result in slow transitions, higher-than-expected extraction of fossil fuels and CO2 emissions, and sub-optimal policy decisions – potentially leading to political reactions and counteractions.

Furthermore, these macroeconomic behavioral constraints are often enforced by additional microeconomic forces that are frequently modeled by game theoretical setups, aiming at studying limit pricing and entry barriers for renewable energy entrants in a concentrated oligopolistic market. Despite the prominence of mitigation policies, the phasing in of renewable energy sources faces domestic and international trade-offs and leakages, highlighting the need for global cooperation to address climate change risks. Key elements include technology transfer, sustainable development finance, poverty alleviation, and economic incentives to encourage participation. However, the absence of a supranational enforcement mechanisms underscores the lack of reliance on voluntary commitments to international agreements.

To study those complex climate challenges and climate risks in the context of macro and micro mechanisms as well as behavioral constraints, we need computational algorithms and appropriate econometrics to observe the results for the design and enactment of policies. Using these techniques, we aim to explore three questions: First, we evaluate to what extent model-guided work that aims at optimal solutions needs to be complemented by behavioral components to succeed in decarbonization policies. Second, we want to assess whether empirical exercises and econometrics can tell us if a carbon pricing strategy or promoting renewable energy production through innovative investments is more successful. Third, to what extent is the strategy of direct investment in renewable energy preferable to a carbon pricing strategy in terms of behavioral forces?

2 Macro View of Behavioral Constraints

In Macroeconomics, the challenge of addressing climate change through economic policy often involves balancing optimal pathways suggested by macroeconomic models with the realities of behavioral constraints. Dynamic Integrated Climate-Economy (DICE) and Dynamic Stochastic General Equilibrium (DSGE) models have been widely used to identify optimal strategies for transitioning to a low-carbon economy. These models excel in highlighting the economic trade-offs and policy implications of various climate strategies, particularly in the context of reducing greenhouse gas emissions.

However, one of the critical limitations of these models is their frequent neglect of behavioral constraints, which play a crucial role in the success or failure of climate policies and influence real-world policy outcomes. These constraints arise from a variety of factors that extend beyond traditional economic calculations, encompassing social and political dimensions that complicate the transition to a low-carbon economy.

2.1 Related literature

In academic and policy circles, carbon pricing is often regarded as a central strategy for addressing climate change. A significant study by Metcalf and Stock (2020), evaluated the impact of carbon taxation on emission reduction using a VAR methodology, drawing from EU data. Känzig (2023) examines the economic effects of carbon pricing by leveraging the institutional characteristics of the European carbon market and high-frequency data on carbon pricing. Yet the carbon tax can also be implemented as carbon-based wealth tax (see Fischermann et al.,2024). The findings indicate that reallocating a portion of the carbon revenues to the groups most impacted can mitigate the economic costs associated with carbon pricing and potentially enhance public support for the policy. Recent work, including studies by Flaherty et al. (2017) and Orlov et al. (2017), has extensively examined the use of carbon taxes and other measures, such as green bonds, while also studying the distributional implications by exploring intergenerational costs and benefits of climate policies.

On the other hand, directed technical change and promotion of investment in cleaner energy sources are suggested by the academic literature. Decarbonization is proposed to be achieved directly through the implementation of innovative renewable energy technologies. In this context, we can refer to Edenhofer et al. (2006), Van Der Ploeg and Withagen (2014), Acemoglu et al. (2012), and Greiner et al. (2014). In particular, Acemoglu et al. (2012) considered both fossil fuel and renewable energy production technologies, along with the substitution of inputs to promote clean technologies for sustainable growth. Generally, studies in this field advocate for innovation and corresponding tax or subsidy schemes to support this shift. Their model introduced a positive elasticity of substitution between the two sectors within an aggregate production function.

Optimal control models, such as DICE, or DSGE, aim to study the optimal transition path to a low-carbon economy (see Nordhaus, 2008). Earlier research primarily focused on mitigation policies in a broad sense, with less attention given to adaptation strategies. In contrast, recent studies have specifically addressed adaptation policies in response to expected climate disasters, such as sea level changes, and have emphasized the importance of adaptation (for more information, see Kaya et al. (1993), Nordhaus and Boyer (2000), Nordhaus (1994, 2008), Tol and Fankhauser (1998), Golosov et al. (2014), and Tol (2007)). In this regard, Bonen et al. (2014) provide a general overview of anticipated future climate-related damages and adaptation policies across different models, while Mittnik et al. (2020) offer an empirical analysis of carbon emissions.

2.2 Model-guided Optimal and behavioral driven decarbonization

Climate change and climate-related risks are currently more significant and complex than any other environmental challenge (Nyambuu and Semmler, 2023; Roy et al., 2024). Given the critical importance of addressing climate change and its risks, efforts have been concentrated on reducing greenhouse gas emissions, particularly CO2, especially in the context of sustainable macroeconomics. These efforts range from mitigation policies – which focus on reducing emissions to slow global warming – to adaptation policies, which involve adjusting systems and practices to minimize the damage caused by the effects of climate change. Additionally, resilience policies aim to enhance the ability of communities and ecosystems to recover from climate-related shocks, such as extreme weather events.

However, even well-designed climate- macro policies may fail or underperform if they do not account for behavioral constraints that influence decision-making. These policies refer to strategies and interventions aimed at addressing climate change and its associated risks, while also taking into account the various factors that shape how individuals and organizations respond to these challenges. These barriers and policies can be assessed at both macro and micro levels. By understanding and addressing behavioral constraints and their effects at these levels, policymakers can design more effective interventions that lead to meaningful action on climate change. In the context of these models and in academic and policy circles, carbon pricing is often regarded as a central strategy for addressing climate change. Therefore, it is important to study and take into account the side effects of carbon pricing.

By putting a price on carbon emissions, this approach aims to incentivize the reduction of greenhouse gas emissions and promote investment in cleaner, renewable energy sources. Yet, what will the price and distributional effects will such a policy be? On the other hand, decarbonization can also be achieved directly through the deployment and integration of innovative renewable energy technologies. To explore the transition to a low-carbon economy, researchers often employ optimal control models such as the Dynamic Integrated Climate-Economy (DICE) model or Dynamic Stochastic General Equilibrium (DSGE) models. These models are designed to analyze the optimal pathways for reducing carbon emissions.

However, a significant limitation of these models is their tendency to overlook actual behavioral forces in markets that can influence the effectiveness of climate policies. These behavioral forces include inertia due to behavioral stickiness, technological lock-ins, irreversibilities, leakages, non-cooperative actions by countries and companies, limited information for agents, and a lack of available substitutes. These constraints are likely to lead to slower transitions, higher-than-expected fossil fuel extraction and CO2 emissions, suboptimal policy decisions, and potentially political resistance.

Arthur (1989) discussed the theory of lock-ins in the development and implementation of technology. In this context, Bonen et al. (2016) argued that DICE-type macroeconomic models can overlook the essential role of resources and fail to fully account for the negative externalities associated with fossil fuels. Furthermore, as demonstrated by Reguant (2021), control constraints can arise from various factors, including lock-ins, irreversibility, leakages, and other causes. Additionally, the original DICE model was created with a focus on mitigation policies. Addressing this issue, Bonen et al. (2016) and Semmler et al. (2021) expanded the model by examining both mitigation and adaptation policies within a climate-macro linkage framework.

Recently, Roy et al. (2024) empirically examined the hypothesis of carbon price market-driven optimal solutions and compared it to an innovation-driven decarbonization strategy. For their empirical work, they used a Regime Switching Co-Integrated VAR (RSCIVAR) econometric model that distinguishes between regimes with and without a carbon tax. If the regime-switching model is rejected based on carbon tax regimes but confirmed when renewable technology is included as a state variable, it suggests that renewable technology is the primary driver of CO2 reduction and output effects. Empirically, Sweden, Denmark, Finland, and Norway have implemented carbon taxes and invested in renewable energy over the past three decades. The results from the regime-switching models, where carbon tax and non-carbon tax regimes are defined, reveal that while output is not significantly affected, the carbon tax regime-dependent impulse response functions show only minor effects on carbon emissions in most of the countries studied. It turns out that, in these countries, renewable energy innovations are more significant drivers of decarbonization.

Moreover, Sen et al. (2024) evaluated the impact of carbon pricing on emissions using a panel dataset of 138 countries from 1981 to 2017. The study finds that carbon pricing, adopted by over 40 countries by 2017, reduces per capita CO2 emissions from fossil fuel combustion by 8 to 12 percent on average, with a 19 to 23 percent decrease observed after 10 years. The results suggest that carbon pricing effectively addresses climate change only by shifting expectations, prompting firms and households to anticipate future costs and adjust their behavior. The study also finds that carbon pricing promotes the substitution of CO2-intensive fuels with cleaner alternatives, and emphasizes the need for the integration of renewable energy and energy efficiency policies as important drivers for decarbonization.

Overall, behavioral drivers such as inertia due to behavioral stickiness, technological lock-ins, irreversibilities, and leakages, as well as non-cooperative behavior by nations and corporations, play a crucial role in shaping the pace and success of the transition. These factors are often compounded by limited information, the unavailability of substitutes, and the resistance to change within established systems. As a result, transitions to a low-carbon economy may proceed more slowly than anticipated under carbon pricing regimes, leading to higher-than-expected fossil fuel extraction, increased CO2 emissions, and suboptimal policy outcomes.

Those behavioral constraints given the reliance on voluntary market reactions due to higher (fossil fuel) energy prices, underscore the critical need for innovative approaches in energy supply overcoming the above challenges. Technically, to address those challenges, the multi-period solution algorithm NMPC (see Gruene et al.,2015) can be proposed, which considers receding horizon decisions under constraints, blending optimal strategies with behavioral realities. This interplay between optimal policies and behavioral constraints helps to reveal the complexity of achieving a low-carbon economy. Other limitations of the market-oriented carbon pricing strategy may arise from the inflation pressure that usually accompanies this strategy, which is known as “fossilflation” (see Chen and Semmler, 2024). Effective mitigation of climate risks thus requires integrating behavioral considerations into policy modeling and measures, emphasizing the need for robust strategies that address both economic and behavioral inertia. Section 3 examines these challenges from a micro-level perspective.

3 Micro View of Behavioral Constraints

While macroeconomic models offer a comprehensive view of the challenges in transitioning to a low-carbon economy, a micro-level analysis reveals the detailed behavioral constraints encountered by individual firms and market participants. The micro view focuses on the strategic interactions and decision-making processes within markets, particularly on how these dynamics impact the entry and growth of renewable energy firms. Understanding these micro-level constraints is essential for addressing the barriers that can hinder the broader adoption of clean technologies and for devising effective policies that facilitate the transition to a sustainable energy future.

A key behavioral constraint at the micro level is the oligopoly structure of the fossil fuel energy supply sector and its pricing behavior, such as limit pricing – a strategy employed by incumbent firms to maintain market dominance. Another crucial aspect of the micro view is non-cooperative behavior among market participants. Non-cooperative behavior refers to actions taken by firms that do not account for the collective well-being or strategic coordination with others. In this context, game theory offers valuable insights into these micro-level constraints by analyzing the strategic behavior of firms in competitive environments.

3.1 Related literature

To understand the micro-level constraints for the transition to a low-carbon economy, it is essential to review the relevant literature that explores the strategic behavior of firms and market dynamics. Key studies investigate the application of game theory to analyze these dynamics, providing insights into how traditional energy companies use pricing strategies to protect their market share and how renewable firms navigate these challenges.

In the transition to a low-carbon economy, prices – particularly relative price dynamics – play a crucial role. In this context, the ECB recently detailed the factors driving price changes during the transition to a low-carbon economy, especially as outdated energy technologies are replaced by new ones (see Schnabel, 2022). This study highlights that climate disasters, spikes in fossil energy prices, and carbon taxes can contribute to “fossilflation”. Additionally, bottlenecks and supply constraints during the shift from carbon-based to renewable energy sources are identified as another source of inflation, termed “greenflation”.

Moreover, the fossil fuel sectors currently in operation are highly oligopolistic, characterized by significant entry barriers, competition restrictions, and limit pricing strategies (Chen and Semmler, 2024). In limit pricing, established companies set prices low enough to prevent new competitors from entering the market. Gaskins (1971) was the first to address the issue of dominant firms encountering competitive fringe entrants, introducing the concept of the dominant firms’ pricing strategy known as “Dynamic Limit Pricing.” Carpenter and Petersen (2002), in an empirical study of small firms, highlighted the significance of internal finance, indicating that the growth of these firms is primarily constrained by these resources. von Stackelberg (1934) pioneered the Stackelberg-Cournot oligopolistic market model, centered around the leader-follower concept. His work was later expanded by research that made significant contributions to advancing computational and algorithmic approaches for solving the Stackelberg model (see Sherali et al. (1983), and Tobin (1992)).

Decision constraints are then incorporated into models, particularly in environmental and climate games and their application to international negotiations. Following the Kyoto Protocol, various international negotiations have been informed by different game-theoretical frameworks. In this context, Dockner et al. (1996) provided a comprehensive study of resource and environmental games, exploring their interconnections. These games address the externalities and side effects of industrial activities, with one focusing on resource extraction and the other on environmental pollution.

In the field of climate protection policy, Nonlinear Model Predictive Control (NMPC) (see Gruene et al., 2015) is a technique that can be effectively applied. NMPC facilitates dynamic interactions among different decision-makers by solving multiple optimization problems simultaneously. This method addresses the interactions between various players, predicting the impact of their actions as well as their opponents’ moves over a given time horizon. The policy equilibrium, known as the Nash equilibrium – a state where each decision-maker has no incentive to alter their strategy given the decisions of others – is achieved by iteratively solving these optimization problems over time (see Di Bartolomeo et al., 2018, 2021, 2023; Saltari et al., 2022).

3.2 Entry Game with Barriers and Limit Pricing

The entry of renewable energy firms into the energy sector is crucial for mitigating climate risks and advancing the transition to a low-carbon economy. When renewable energy companies enter a market dominated by conventional energy producers, they encounter a strategic landscape shaped by entry games involving limit pricing. Limit pricing – where incumbent firms set prices low enough to deter new entrants – is a key tactic for maintaining market dominance by traditional energy companies. This strategy requires incumbents to balance setting prices low enough to prevent entry while ensuring profitability. For renewable energy firms, entering a market characterized by limit pricing presents significant risks and demands careful strategic planning. These firms may find it challenging to compete with lower prices without compromising their profitability or long-term viability.

In this context, Semmler et al. (2022) offered a game-theoretic model illustrating the competition between incumbent and new firms. In their framework, incumbents set prices while new entrants adjust their quantities in response. They explored the dynamics of a market where established fossil fuel suppliers face competition from renewable energy firms. The incumbents have better access to financial markets, whereas the new entrants rely on internal financing for their growth. Their study also examined the impact of public support, such as subsidies, on renewable energy firms. Their findings underscored the significance of initial cash flow levels. They found that when new firms enter the market with positive cash flows, incumbents initially do not react aggressively. However, over time, incumbents may start to set prices strategically to hinder further entry. Conversely, when new firms enter with negative cash flows, they can still persist and gradually increase their profits in the longer run if they benefit from supportive policies, technological advances, and financial assistance. The results, were obtained using a Nonlinear Model Predictive Control (NMPC) algorithm.

It should be noted that the effectiveness of limit pricing as a barrier to entry in the energy sector is complex and influenced by various factors. Technological advancements in renewable energy and policy interventions – such as subsidies for renewables or carbon pricing mechanisms – can reshape the market landscape by lowering entry barriers and diminishing the effectiveness of limit pricing as a deterrent.

In summary, analyzing the entry game in the energy sector through the perspectives of limit pricing and effective climate policy reveals a complex interaction between economic tactics and regulatory measures. Crafting effective policies that address both economic and behavioral entry barriers is crucial for helping renewable energy firms navigate incumbents' limit pricing strategies and contribute to a more sustainable energy future in terms of renewable energy supply.

3.3 Non-Cooperative Behaviour

Non-cooperation in the context of climate change refers to the reluctance or refusal of nations to collaborate on global mitigation efforts. This behavior is driven by the perception that individual countries can benefit from free-riding, where they reap the advantages of global GHG reductions without bearing the costs of implementing stringent environmental policies themselves. The short-term economic gains associated with noncooperation often overshadow the long-term benefits of global cooperation, particularly when political and economic systems are more attuned to immediate outcomes rather than future risks, thus driven by short-termism.

Di Bartolomeo et al. (2023) address the complexities of mitigating climate risks, emphasizing the global nature of greenhouse gas (GHG) emissions and the challenges posed by behavioral constraints, particularly non-cooperation among nations. The non-cooperative behavior results in a significant externality, where the cost of GHG emissions is not internalized by individual nations, leading to a collective action problem. The global nature of climate risks means that no single country can effectively mitigate the risks on its own; instead, coordinated efforts are essential. However, the lack of cooperation exacerbates the problem, as countries may continue to emit GHGs at high levels, knowing that the consequences of their actions are distributed globally rather than being confined to their own borders.

Non-cooperation as a behavioral constraint significantly undermines the development and implementation of effective climate policies. It underscores the need for international frameworks that can incentivize cooperation, align short-term actions with long-term global interests, and address the disparities in the distribution of climate change impacts and mitigation responsibilities. Without overcoming this constraint, efforts to mitigate climate risks are likely to remain insufficient, leading to continued environmental degradation and heightened global vulnerabilities.

4 Conclusions

The transition to a low-carbon economy is a multifaceted challenge that requires balancing theoretical models with the complexities of real-world behavioral constraints. While carbon pricing and directed technical change are often promoted as central strategies for decarbonization, the effectiveness of these approaches is significantly influenced by behavioral drivers at both macro and micro levels. These include inertia due to behavioral stickiness, technological lock-ins, and non-cooperative behaviors, all of which can slow down the transition process and lead to suboptimal policy outcomes.

At the macro level, economic models like DICE and DSGE provide valuable insights into optimal pathways for reducing greenhouse gas emissions. However, these models, frequently based on carbon pricing strategies, often fail to account for the behavioral constraints that can derail even the most well-designed policies. The micro-level analysis further reveals the strategic interactions among market participants, particularly the challenges faced by renewable energy firms in entering markets dominated by incumbent fossil fuel companies. These challenges are compounded by strategies such as limit pricing and non-cooperative behavior, which can prevent the broader adoption of clean technologies.

Addressing these behavioral constraints is crucial for the successful implementation of climate policies and in our view, it seems that there are fewer behavioral constraints in the strategy to incentivize and promote the phasing in of renewable energy supply sources through a cooperation between the private and public sectors. Renewable energy supply of roughly 40% in the Nordic countries, as Roy et al (2024) show, was achieved by public support of a rising renewable energy share in total energy; meanwhile, renewable energy production in the Nordic countries seems to have become quite profitable. Policy reactions to this strategy were minor in the Nordic countries. The energy transition strategies require not only refining economic models to better incorporate behavioral factors but also developing energy innovations and policy interventions that account for the realities of market dynamics and international cooperation. Integrating these considerations into climate policy design will enhance the effectiveness of mitigation efforts and facilitate a smoother transition to a sustainable, low-carbon future.

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