Political Turnover and the Design of Carbon Contracts for Difference

Nicolas Pinsonneault[†]

[†]*Department of Applied Economics, HEC Montréal* *

Abstract

We study how political turnover affects clean investment under carbon pricing uncertainty. In a dynamic model with electoral risk, firms invest in emissions-reducing technologies while facing uncertain future carbon taxes. Carbon Contracts for Difference (CCfDs) reduce carbon price risk and can mitigate underinvestment by stabilising the expected return to abatement. However, once output is endogenous, CCfDs alter production incentives. We show that while an appropriately chosen strike price can restore strong investment incentives, CCfDs act as state-contingent transfers, leading to over-production when carbon prices are low and under-production when they are high. We characterise the optimal strike price and show that it lies between the policy preferences of competing political parties and that it increases with the probability of policy continuity. Finally, we show that limiting the volume of output eligible for compensation reduces production distortions while preserving investment incentives.

*HEC Montréal, 3000 chemin de la Côte-Sainte-Catherine, Montréal, QC, H3T 2A7, Canada. E-mail: nicolas.pinsonneault@hec.ca

1 Introduction

Climate policy, especially carbon taxes, is a key instrument in global efforts to combat climate change by putting a price on carbon emissions. As of today, numerous countries have implemented various forms of carbon pricing, although the scope, structure, and effectiveness of these policies vary significantly across regions (Postic and Fetet (2020)). Politically, the adoption and sustainability of carbon taxes are fraught with unpredictability. Policymaking, among other things, is subject to electoral cycles (Harstad (2020)), lobbying by interest groups (Kalkuhl et al. (2020)), and shifts in public opinion (Ewald et al. (2022)). These factors can result in abrupt policy reversals or diluted tax implementations, undermining their potential impact. As Brunner et al. (2012) put it, from a public choice perspective, the government consists of changing policymakers with evolving preferences. Different stakeholders, with conflicting interests, strive to shape policies to their benefit. Policy risk also arises from shifting political majorities, leading to alternating special interests being represented (Strausz (2009)). Consequently, carbon policy can vary significantly depending on the ruling political party, influenced by their ideologies and constituencies. For instance, political resistance has led to the rollback or weakening of carbon tax policies in various jurisdictions, reflecting the contentious nature of such measures. A notable example of political resistance leading to the rollback of carbon tax policies is the case of Australia. In 2012, the Australian government, led by the Labor Party under Prime Minister Julia Gillard, introduced a carbon pricing mechanism stemming from the 2011 *Clean Energy Act*. Shortly after, Liberal-National Coalition, led by Tony Abbott, won the 2013 general election. True to his campaign promise, the Abbott government repealed the carbon tax in 2014, just two years after its implementation. More recently, in Canada, the Carney government all but ended the consumer carbon tax by setting the effective federal fuel charge to 0$ as of April 1st 2025.

Central to these issues is the problem of time-inconsistency. In their seminal pa-

per, Kydland and Prescott (1977) famously mentioned that "economic planning is not a game against nature but, rather, a game against rational economic agents". The essence of the time consistency problem is that a policy considered optimal by economic policymakers initially, when it can shape the expectations of households and firms, often ends up not being implemented later, once those expectations have already influenced private behavior. Consequently, policymakers tend to revise their decisions. This phenomenon often results from the differing timelines of political cycles and the slow, cumulative nature of environmental impacts. While politicians may prioritize policies that yield immediate benefits to secure re-election or public approval, the long-term nature of climate change requires sustained and consistent efforts over decades. Consequently, this misalignment between long term problems and short term rewards can lead to insufficient or inconsistent policy measures, undermining the overall effectiveness of climate action and most importantly, create a hold-up problem (Williamson (1975)), where firms under-invest as they fear being stuck with stranded assets (Kalkuhl et al. (2020)).

Solutions that have been explored include establishing independent climate institutions (Helm et al. (2003)), setting legally binding emission targets, and integrating climate goals into broader economic planning, such as making contingent trade agreements (Harstad (2024)) or targeting investment subsidies into sectors that are complementary to future green investment possibilities (Harstad (2020)). One approach to mitigating policy risk is the use of Carbon Contracts for Difference (*CCfDs*). These financial instruments function by ensuring that firms receive compensation if the actual carbon price falls below a pre-agreed strike price. Conversely, if the market carbon price exceeds the strike price, firms return the excess to the government. *CCfDs* thus serve to stabilize expectations and de-risk investments in low-carbon technologies, providing a mechanism through which governments can credibly guarantee climate policy goals even in the face of political turnover (Chiappinelli and

Neuhoff (2020)). While contracts for difference have been deployed in some jurisdictions, such as in renewable electricity markets (Chiappinelli and Neuhoff (2020)) or through the *klimaschutzverträge* program in Germany (**?**), their broader implications regarding policy continuity, investment behavior, and democratic governance remain underexplored.

This paper contributes to the literature by examining the role of *CCfDs* in addressing the hold-up problem and improving policy implementation in the presence of political uncertainty. We develop a theoretical framework that models firm behavior under policy uncertainty and demonstrate how *CCfDs*, under strict conditions, can act as an implementation device that can enable a desired investment outcome. We show that CCfDs can provide firms with a level of certainty that traditional carbon pricing mechanisms fail to achieve. However, while *CCfDs* can enhance policy credibility and reduce uncertainty for firms, they do not necessarily implement the desired *ex-ante* level of production or carbon intensity reductions. Since *CCfDs* provide a subsidy-like effect by stabilizing carbon prices, they may encourage firms to increase their output beyond what would be socially optimal under a fully credible carbon pricing regime. This can trigger a rebound effect, where the increased production partially offsets the intended environmental benefits of the policy. In particular, if the *CCfD* strike price is set too high, firms might overproduce and emit more than they would under a well-functioning and predictable carbon tax, highlighting a fundamental limitation of *CCfDs* in fully aligning private incentives with the social cost of carbon.The analysis shows that the strike price plays a pivotal role: a higher strike price enhances the incentive to invest but increases expected fiscal transfers and production distortions, whereas a lower strike price reduces fiscal exposure at the cost of weaker abatement effort. The optimal contract balances these forces, leading to a strike price that lies between the policy preferences of the two parties and varies with the incumbent's probability of re-election.

We then extend the analysis to the case where the government limits the total quantity of output eligible for compensation. Such a cap reduces excessive production in low-price states and constrains the "over-subsidy" problem without undermining investment incentives. This design feature captures a broader efficiency trade-off: instruments that strengthen investment incentives under policy uncertainty inevitably introduce distortions in production and fiscal outcomes. By constraining the range of payments, the contract limits these distortions while preserving its role in stabilizing expectations. The model therefore highlights that the effectiveness of climate policy depends not only on the credibility of commitments but also on how contractual design shapes green investment and production. Finally, this paper is mainly concerned with the design of *CCfDs*. It doesn't engage with the question of whether such contracts are desirable in the first place, neither does it aim at comparing *CCfDs* with other instruments.

The remainder of the paper is structured as follows. Section 2 situates the analysis within the broader literature on political commitment, time inconsistency, and climate policy uncertainty. Section 3 presents the theoretical framework, describing the firm's investment and production decisions under political turnover. Section 4 introduces Carbon Contracts for Difference as a policy instrument and analyzes how their design affects abatement and output choices. Section 5 characterizes the optimal strike price, highlighting the trade-off between strengthening investment incentives and limiting fiscal and allocative distortions. Section 6 extends the analysis to contracts with an upper bound on eligible output and shows how such a cap mitigates the distortions arising from linear payment schemes. Section 7 discusses the broader implications of the results for the design of credible and efficient climate policy. Section 8 concludes.

2 Relation to the literature

2.1 Commitment, political cycles and time inconsistency

Commitment in economics refers to the ability of policymakers to make credible promises about future policies. The importance of commitment has been highlighted in numerous studies, most famously including Kydland and Prescott (1977). They argue that policymakers, if left unchecked, may have incentives to deviate from previously announced policies to achieve short-term objectives, leading to suboptimal long-term outcomes. Rules ensure predictability and prevent policymakers from changing course based on short-term incentives, which can lead to time inconsistency. This problem is particularly pronounced in monetary and fiscal policies, where governments may renege on commitments to low inflation or sustainable debt levels.

One proposed solution to the commitment problem is the establishment of independent institutions, such as central banks, which can credibly commit to policy objectives without political interference (Rogoff (1985)). By insulating decision-making from short-term political pressures, these institutions enhance policy credibility and reduce uncertainty for economic agents. Similarly, fiscal rules and legally binding policy frameworks have been implemented in various countries to reinforce commitment to long-term objectives (Alesina and Perotti (1996)). The interaction between commitment and political cycles has significant implications for investment and long-term economic growth. When governments lack credibility, firms and investors face uncertainty about future policies, leading to suboptimal investment decisions. Alesina and Tabellini (1990) argue that short-term political pressures may lead to suboptimal public investment decisions, where governments prioritize projects with immediate electoral benefits rather than those that enhance long-term productivity. This dynamic can distort capital allocation, leading to inefficiencies in infrastructure and public services that are crucial for sustained economic growth. Additionally, firms

operating in environments with high political risk tend to adopt more conservative investment strategies, preferring shorter payback periods and lower capital commitments (Gulen and Ion (2016)). This conservative approach can hinder innovation and long-term technological advancements, further affecting national competitiveness. In response, Harstad (2020) argues that strategically designed investment subsidies can mitigate this problem by directing support toward technologies that facilitate further decarbonization over time. Such subsidies target sectors that are complementary to future low-carbon investments, ensuring that initial commitments lead to sustained emissions reductions.

2.2 Incomplete contracts and implementation

The central idea within implementation theory is to design rules or mechanisms that ensure a particular social choice function (a rule mapping preferences to outcomes) is implementable, meaning it arises as the equilibrium outcome of a game induced by the mechanism. A core challenge lies in reconciling incentive compatibility with the broader goals of efficiency, equity, or welfare maximization. Implementation theory examines how economic policies or mechanisms can be designed to achieve desired outcomes despite strategic behavior by agents. Originally developed within mechanism design (Maskin (1999)), implementation theory has been widely applied in public economics, contract theory, and institutional design.

A key insight from implementation theory is that policies must be incentive-compatible to ensure compliance. Governments face challenges in designing mechanisms that align private incentives with socially optimal outcomes, especially when there is asymmetric information or strategic manipulation (Moore and Repullo (1988)). For example, in public-private partnerships, incomplete contracts may lead to renegotiation that benefit politically connected firms rather than optimizing efficiency (Tirole (1999)). From an investment perspective, implementation theory suggests

that governments should design self-enforcing agreements that remain robust to political and economic fluctuations. One approach is the use of commitment devices, such as independent regulatory agencies or automatic stabilizers, which reduce the discretionary power of policymakers and enhance credibility (Acemoglu (2003)).In the context of climate policy, and central to our paper, implementation theory supports the design of mechanisms such as *Carbon Contracts for Difference*, where governments commit to predetermined carbon pricing structures, reducing uncertainty for investors in low-carbon technologies.

2.3 Carbon contracts for difference

Carbon Contracts for Difference (*CCfDs*) are financial instruments designed to incentivize investment in low-carbon technologies by mitigating risks associated with carbon pricing and in some cases, with market uncertainties[1]. In the context of our paper, *CCfD* payments are triggered when the effective carbon price differs from a previously determined strike price. Therefore, we concentrate our analysis on the carbon price risk. Note that if the carbon price falls below the strike, the firm gets compensated for the difference. If the carbon price rises above the strike, the payment burden is reversed and the firm pays the government. Some previous work argues that *CCfDs* could be particularly useful for capital-intensive technologies like green hydrogen production (Chaton and Metta-Versmessen (2023)), carbon capture and storage (CCS), and advanced renewable energy systems, where high upfront costs and long payback periods often deter private investment (Richstein and Neuhoff (2022)).

Alternatively, previous work has highlighted the importance of contract design, emphasizing strike prices (Chiappinelli and Neuhoff (2020)) and durations that balance investor (firms) incentives with government cost-effectiveness, as explored by

[1]This is notably the case in Germany, where *CCfDs* also cover the difference in CAPEX and OPEX of cleaner processes, compared to a less climate-friendly benchmark, see (Federal Ministry for Economic Affairs and Climate Action (BMWK) (2022))

Richstein and Neuhoff (2022). However, while *CCfDs* offer significant benefits, their design must balance government expenditure with efficiency concerns. Setting the strike price too high could lead to inefficiently large government payouts, while setting it too low may fail to incentivize sufficient investment. Moreover, *CCfDs* do not directly impose emissions caps, meaning that without complementary policies, they could inadvertently lead to increased overall production and emissions—a phenomenon similar to a rebound effect.

Recent policy experience in Germany provides a concrete illustration of these design trade-offs. Germany has introduced *Klimaschutzverträge* (climate protection contracts) as a large-scale implementation of CCfDs for energy-intensive industries, targeting sectors such as steel, cement, chemicals, and paper. These contracts are awarded through competitive auctions and are project-based, with payments calculated relative to a benchmark emissions intensity associated with a conventional production process (Federal Ministry for Economic Affairs and Climate Action (BMWK) (2022)). In contrast to stylized CCfD formulations, German contracts explicitly cover both operating cost differences and, in some cases, capital cost components, reflecting the fact that many industrial decarbonisation technologies remain structurally unprofitable even under anticipated future carbon prices.

Therefore, an important feature of the German scheme is that CCfDs are used not only to hedge firms against carbon price volatility, but also to selectively promote the deployment of specific low-carbon processes. By stabilising the effective carbon price relevant for the firm's investment decision over a long horizon (typically around 15 years), the contracts reduce downside risk associated with uncertain future carbon prices under the EU ETS. At the same time, eligibility is restricted to predefined technologies and contractual volumes, and payments are calculated only for emissions reductions generated within the scope of the contract. As emphasised in

recent policy and academic analyses, this design reflects the objective of accelerating investment in transformative technologies rather than subsidising production more generally (Richstein and Neuhoff (2022)).

In this paper, the role of Carbon Contracts for Difference is interpreted primarily through their de-risking function with respect to carbon prices. Rather than viewing CCfDs as instruments that guarantee the profitability of a given production process, we model them as policies that reduce firms' exposure to uncertainty in future carbon prices by stabilising the effective carbon cost relevant for production and investment decisions. By narrowing the dispersion of expected payoffs associated with low-carbon technologies, *CCfDs* alter the relative attractiveness of alternative production processes, particularly in settings where investment is capital-intensive and payoffs are highly sensitive to carbon price realisations. The analysis therefore focuses on how this reduction in carbon price risk interacts with firms' production choices and the implementation of CCfDs, abstracting from other sources of uncertainty and complementary policy objectives.

We build on these insights by examining how *CCfDs* function as an implementation device in the face of political uncertainty. Notably, we allow the firm to make a production volume decision, which to our knowledge, remains unexplored by papers such as Chiappinelli and Neuhoff (2020). While they reduce investment risk for firms, their effectiveness in fully aligning private incentives with long-term welfare goals remains an open question and our conclusions show that one must be cautious when designing such contracts.

3 The hold-up problem under uncertainty (without *CCfDs*)

3.1 The timing of the game

Consider a simple two-party setting. In Period 1, the incumbent government announces its proposed second period carbon tax policy, denoted by τ^I. The challenger also announces its own proposed tax rate, τ^C. There is a probability λ that the incumbent remains in power. A representative firm then chooses its level of investment in abatement technology, e, based on the information available in period 1 and to be effective in period 2.

In period 2, depending on the outcome of the political process, either the incumbent or the challenger is elected: if the incumbent is reappointed (with probability λ), tax $\tau = \tau^I$ is implemented; otherwise, $\tau = \tau^C$. Contrarily to Chiappinelli and Neuhoff (2020), where the representative firm's output is normalized to one, and where its only choice variable is the (clean) investment level, we also allow the representative firm to optimize on its production level. We later show that this distinction can generate distortions, which can compromise the effectiveness of *CCfDs*.

3.2 The representative firm's problem

The representative firm can produce q units of a polluting good at cost $C(q)$, where $C'(q) > 0$ and $C''(q) > 0$. The firm sells the good for price p and it pays a carbon tax τ on its level of emissions $e \cdot q$, where e is its carbon intensity and q is output. We make the simplification that the firm is a price taker and that it operates in an international setting such that it cannot transfer the carbon-tax burden to consumers in the short-run. The representative firm can reduce its carbon intensity by investing in reducing e from a baseline $\bar{e}$. This can be made at cost $K(e)$ where $K'(e) < 0$ and

$K''(e) > 0$. The profit function is therefore given by

$$\pi = pq - e\tau q - C(q) - K(e) \tag{1}$$

The problem is solved by backward induction: starting from the firm's optimal production choice in period 2 and then determining its investment in abatement at time 1. The firm's optimization problem can thus be written as:

$$\max_e \mathbb{E}[\pi] = \mathbb{E}\left[\underbrace{\max_q \left(pq - e\tau q - C(q)\right)}_{\text{period 2}} - K(e)\right] \tag{2}$$

Solving by backward induction, we get the second-period first order condition with respect to q

$$p - \tau \cdot e^u(\lambda, \tau^I, \tau^C) = \frac{\partial C(q)}{\partial q} \tag{3}$$

Which classically states that the marginal benefit of producing more, which is the sales price minus the tax payments, is equal to the marginal cost of production. Back in period one, the maximization problem then becomes

$$\max_e \mathbb{E}[\pi] = \lambda\left[pq_u^I - \tau^I e q_u^I - C(q_u^I)\right] + (1-\lambda)\left[pq_u^C - \tau^C e q_u^C - C(q^C)\right] - K(e) \tag{4}$$

Where q_u^I and q_u^C are the 2 *ex-ante* uncertain possible production levels and which depend on whether or not the incumbent is reappointed. They each are the solution to (3), for each $\tau \in \{\tau^I, \tau^C\}$ The period 1 first order condition is given by

$$\lambda\left[p\frac{\partial q_u^I(e,\tau^I)}{\partial e} - \tau^I q_u^I(e,\tau^I) - e\tau^I \cdot \frac{\partial q_u^I(e,\tau^I)}{\partial e} - \frac{\partial C\left(q_u^I(e,\tau^I)\right)}{\partial q}\frac{\partial q_u^I(e,\tau^I)}{\partial e}\right]$$
$$+(1-\lambda)\left[p\frac{\partial q_u^C(e,\tau^C)}{\partial e} - \tau^C q_u^C(e,\tau^C) - e\tau^C \cdot \frac{\partial q_u^C(e,\tau^C)}{\partial e} - \frac{\partial C\left(q_u^C(e,\tau^C)\right)}{\partial q}\frac{\partial q_u^C(e,\tau^C)}{\partial e}\right] - \frac{\partial K(e)}{\partial e} = 0$$

rearranging and invoking the envelope theorem,

$$-\frac{\partial K(e)}{\partial e} = \lambda \left[\tau^I q_u^I(e, \tau^I)\right] + (1-\lambda)\left[\tau^C q_u^C(e, \tau^C)\right] \tag{5}$$

Equation (5) yields the solution $e^u(\lambda, \tau^I, \tau^C)$, which is the carbon intensity choice under uncertainty, and states that the marginal benefit of reducing the per-good carbon intensity is equal to the expected savings in total tax payments from doing so. It follows that the higher the expected tax τ, the more the firm will choose to abate. More precisely, in a two party setting, this carbon intensity decision is a function of both parties' announced tax, but also of the instantaneous probability λ that the incumbent government will remain in power in period 2.

This result highlights the importance of policy credibility in influencing firms' abatement decisions. If firms anticipate significant policy uncertainty, they may under-invest in abatement (from the incumbent's point of view) due to the risk of a lower tax in the future. This aligns with the broader literature on policy-induced investment under uncertainty, where firms discount the effectiveness of future policies when they lack commitment mechanisms.

4 Carbon Contracts for difference

We now turn to the case where the government can provide carbon contracts for difference (*CCfDs*). These contracts generate side-payments as soon as the effective carbon price, $\tau \in \{\tau^I, \tau^C\}$ diverges from the contract's strike price τ_s. Functionally, *CCfDs* operate similarly to existing contracts for difference (May et al. (2018), Kristiansen (2004)) for renewable energy, but with a focus on carbon emissions and carbon pricing. Instead of compensating for the difference between a fixed electricity price and the fluctuating market price, the public entity involved would cover the difference between a predetermined carbon price (strike price, or τ_s) and the actual

market price for carbon emissions. Thus, *CCfDs* enable emission offset project developers to lock in a consistent and predictable carbon price throughout the contract term and the project's lifespan. Essentially, they serve as a hedge against carbon market risks or fluctuations in carbon pricing policies. We make no assumption on the nature of the strike price, other than it must be such that the contract is incentive compatible for the firm. This will be explored in section further sections.

We make the deliberate decision to model *CCfDs* such that they do not exert an active influence on policy expectations in the same way as deficit accumulation. In Alesina and Tabellini (1990), the expectation of higher debt levels affects the economic behavior of future governments, forcing them to adjust taxation and expenditure plans accordingly. In this paper, *CCfDs*, on the other hand, do not shape the policy preferences of future governments; they only ensure that pre-agreed transfers occur regardless of subsequent policy shifts. This means that while debt accumulation can create strategic distortions in fiscal policy, *CCfDs* operate more as financial instruments than as mechanisms of political constraint.

Unlike public debt, which directly affects the government's aggregate budget and influences macroeconomic conditions, *CCfDs* only generate financial transfers tied to carbon price deviations. While these transfers can be significant at the sectoral level, we assume that they do not impose broad fiscal constraints that would systematically alter future policy decisions. In contrast, public debt directly impacts a government's ability to set spending and taxation priorities, making it a powerful tool for shaping policy expectations. By modeling *CCfDs* as compensation mechanisms rather than as binding commitments, we capture their role in mitigating investment risks without assuming they fundamentally restrict the policy space of future administrations. We however think that the commitment question is a central one, although outside the scope of the paper.

4.1 The sequential problem with *CCfDs*

Consider the following period 2 payment rule from the *Carbon Contract for Difference* mechanism

$$CCfD \text{ payment} = (\bar{e} - e)(\tau_s - \tau)q \tag{6}$$

Where τ_s is the strike price of the contract, which is determined in period 1 and where $(\bar{e} - e)$ is the measurable effort in reducing the carbon intensity from the benchmark $\bar{e}$[2], where $\bar{e} \geq e$. This baseline can be viewed as a business-as-usual scenario, where the representative firm makes no effort in reducing its carbon intensity compared to the industry baseline. Payments can go either direction: if $\tau < \tau_s$, the government compensates the firm, but if $\tau > \tau_s$, the firm has to pay the government.

The new profit function is given by

$$\pi = pq - e\tau q + (\tau_s - \tau)(\bar{e} - e)q - C(q) - K(e) \tag{7}$$

The firm's maximization problem with *CCfDs* is given by

$$\max_e \mathbb{E}\left[\underbrace{\max_q \left(pq - e\tau q + \underbrace{(\bar{e} - e)(\tau_s - \tau)q}_{CCfD} - C(q) \right)}_{\text{period 2}} - K(e)\right] \tag{8}$$

Starting with the period 2 problem, we get the first-order condition for output,

$$p - \tau \cdot e(\tau^I, \tau^C, \lambda, \tau_s) + (\bar{e} - e(\tau^I, \tau^C, \lambda, \tau_s)) \cdot (\tau_s - \tau) = \frac{\partial C(q)}{\partial q} \tag{9}$$

Where, $\tau \in \{\tau^I, \tau^C\}$. When $\tau_s > \tau$, that transfer is strictly increasing in q. This is

[2]This can be interpreted as an industry-wide reference carbon intensity. In Europe, for example, that benchmark is set based on the 10% most efficient processes for a given industry. See https://eur-lex.europa.eu/eli/reg_impl/2021/447/oj

akin to a subsidy, which is added on to the sale price. When $\tau = \tau_s$, it is straightforward to see that no *CCfD* payments are made, and that (9) resembles (3).

In expectations, (9) is expressed as

$$\mathbb{E}\left[p - \tau \cdot e(\lambda, \tau^I, \tau^C, \tau_s) + \left[\bar{e} - e(\lambda, \tau^I, \tau^C, \tau_s)\right](\tau_s - \tau) - \frac{\partial C(q)}{\partial q}\right] = 0$$

Where,

$$\begin{aligned}
&\lambda\left[p - \tau^I e(\lambda, \tau^I, \tau^C, \tau_s) + \left[\bar{e} - e(\lambda, \tau^I, \tau^C, \tau_s)\right](\tau_s - \tau^I)\right] \\
+(1-\lambda)&\left[p - \tau^C e(\lambda, \tau^I, \tau^C, \tau_s) + \left[\bar{e} - e(\lambda, \tau^I, \tau^C, \tau_s)\right](\tau_s - \tau^C)\right] \\
&= \lambda\frac{\partial C(q^I)}{\partial q} + (1-\lambda)\frac{\partial C(q^C)}{\partial q} \qquad (10)
\end{aligned}$$

As before, the expected level of output $q^{ccfd}(e, \tau^I, \tau^C, \lambda, \tau_s)$ is a function of both parties' tax policy as well as of the probability that the incumbent remains in power. However, now that firms have access to *CCfDs*, they also take the strike price τ_s into account, as it dictates the size of the expected future transfers. Going back to the first period's problem and taking the first-order condition with respect to e,

$$\begin{aligned}
&\lambda\Bigg[p\frac{\partial q^I(e, \tau^I, \tau_s)}{\partial e} - \tau^I q^I(e, \tau^I, \tau_s) - e\tau^I \cdot \frac{\partial q^I(e, \tau^I, \tau_s)}{\partial e} + \bar{e}(\tau_s - \tau^I)\frac{\partial q^I(e, \tau^I, \tau_s)}{\partial e} \\
&\quad +(\tau_s - \tau^I)q^I(e, \tau^I) - e(\tau_s - \tau)\frac{\partial q^I(e, \tau^I, \tau_s)}{\partial e} - \frac{\partial C\left(q^I(e, \tau^I, \tau_s)\right)}{\partial q}\frac{\partial q^I(e, \tau^C, \tau_s)}{\partial e}\Bigg] \\
+(1-\lambda)&\Bigg[p\frac{\partial q^C(e, \tau^C, \tau_s)}{\partial e} - \tau^C q^C(e, \tau^C, \tau_s) - e\tau^C \cdot \frac{\partial q^C(e, \tau^C, \tau_s)}{\partial e} + \bar{e}(\tau_s - \tau^I)\frac{\partial q^I(e, \tau^I, \tau_s)}{\partial e} \\
+(\tau_s - \tau^I)q^I(e, \tau^I, \tau_s) &- (\tau_s - \tau)\frac{\partial q^I(e, \tau^I, \tau_s)}{\partial e} - \frac{\partial C\left(q^C(e, \tau^C, \tau_s)\right)}{\partial q}\frac{\partial q^C(e, \tau^C, \tau_s)}{\partial e}\Bigg] - \frac{\partial K(e)}{\partial e} = 0
\end{aligned} \qquad (11)$$

By the envelope theorem, using (9), (11) becomes

$$\begin{aligned}
&\lambda\Big[\tau^I q^I(e, \tau^I, \tau_s) + (\tau_s - \tau^I)q^I(e, \tau^I, \tau_s)\Big] \\
+(1-\lambda)&\Big[\tau^C q^C(e, \tau^C, \tau_s) + (\tau_s - \tau^C)q^C(e, \tau^C, \tau_s)\Big] = -\frac{\partial K(e)}{\partial e}
\end{aligned}$$

which yields

$$\tau_s \left[\lambda q^I(e, \tau^I, \tau_s) + (1-\lambda) q^C(e, \tau^C, \tau_s)\right] = -\frac{\partial K(e)}{\partial e} \tag{12}$$

This states that the marginal cost of reducing the per-good carbon intensity is equal to the expected savings in total tax payments from doing so. Now that the firm has access to carbon contracts for difference, the only part where uncertainty plays a role with regards to tax savings is through the period 1 expectation of the choice of $q^{ccfd}(e, \tau^I, \tau^C, \lambda, \tau_s)$ in the second period. This is the case since *CCfD* payments act as a compensation mechanism for any deviation from the strike price.

Since the firm no longer has to worry about policy reversals or fluctuations in tax rates, it can make its investment decision based on a stable and predictable tax framework. This encourages greater abatement investment, as firms can confidently expect a return on their investments in emissions reduction. Unlike the full uncertainty case without *CCfDs*, where firms might hesitate to invest due to the risk of a lower-than-expected tax, *CCfDs* provide a guaranteed financial incentive to reduce emissions, leading to a higher level of abatement investment than would otherwise be the case. However, *CCfDs* do more than just stabilize expectations; they also change the firm's production incentives. Under uncertainty, a lower-than-expected tax would have benefited the firm in two ways: first, by reducing its direct tax burden, and second, by enabling a higher level of production since the cost per unit of emissions would be lower. With *CCfDs*, this is effectively neutralized because any deviation in the carbon price is compensated through the contract mechanism. The firm no longer experiences a gain from lower taxes, as the difference is automatically adjusted through *CCfD* payments. This means that the only remaining source of uncertainty comes from the expected production that still depends on the expected tax, but is presumably less volatile than in the full uncertainty case.

Hence, we will discuss that an additional consequence of *CCfDs* is their potential to induce distortions in production. Because the *CCfD* structure effectively acts as a subsidy when the realized tax falls below the strike price, firms may have an incentive to increase production beyond socially optimal levels. This is particularly relevant in cases where the strike price is set too high, as firms could then receive substantial compensation payments while continuing to produce at a high level, partially offsetting the intended emissions reductions. The next section is dedicated to the study of the role of *CCfDs* in implementing the incumbent government's subjective optimal level of carbon intensity (e) and production (q), where we study the aforementioned issues in more detail.

4.2 The implementation problem

A natural benchmark for the performance of CCfDs would be whether they can implement the incumbent's preferred level of emissions, $E = eq$, under full commitment. In this environment, however, such an aggregate criterion is misleading because the contract and the political friction operate on two distinct margins. The firm chooses its emissions intensity e ex ante, under political uncertainty, and this sunk investment determines both abatement costs and the base for CCfD payments. Output q, by contrast, is chosen ex post, after the election outcome and the realized tax $\tau \in \{\tau^I, \tau^C\}$ are known, and it reacts differently in each political state. A single contract parameter, the strike price τ_s, therefore cannot in general discipline both margins simultaneously. For this reason, we define the incumbent's full-commitment benchmark as a pair (e^{I*}, q^{I*}) and ask whether there exists a strike price τ_s that induces the same intensity and output choices when the firm optimally responds to the CCfD. The analysis below shows that CCfDs can at best recover the incumbent's desired intensity for a restricted range of political turnover probabilities, but necessarily distort output—leading to over-production in low-tax states and under-production in high-tax states from the incumbent's perspective, even when the contract is accepted

by the firm. In other words, implementation in emissions is not the right benchmark because the contract operates on two sequential decisions. What matters is which margin *CCfDs* can align with the incumbent's certainty benchmark and which margin they therefore inevitably distort.

4.2.1 Defining the incumbent's optimal outcome

Under certainty, the firm's period-1 problem can be written as

$$\max_{e} \pi = \underbrace{\max_{q} \left(pq - e\tau q - C(q)\right)}_{\text{period 2}} - K(e)$$

Let $\tau = \tau^I$ represent a credibly announced carbon tax, which is set equal to the social cost of carbon as perceived by the incumbent government in period 1 and which is implemented in period 2 with probability $\lambda = 1$. Precisely, this specification reflects the optimal policy choice from the perspective of the initial government, given its own assessment of the social cost of carbon. We remain agnostic with respect to the normative validity of this particular valuation of the social cost of carbon and therefore make no ethical argument regarding the choice of τ^I. The corresponding first-order conditions that characterize this policy choice are given by

$$p - \tau^I e^{I*}(\tau^I) = \frac{\partial C(q^I)}{\partial q} \text{ period 2}$$

and

$$-\frac{\partial K(e^I)}{\partial e} = \tau^I \cdot q^{I*}(e^I, \tau^I) \text{ period 1}$$

Where both $C(q)$ and $-K(e)$ are strictly convex and at least twice differentiable.

From the incumbent government's perspective, using a *CCfD* regime as an implemen-

tation device would imply that both $e^{ccfd}(\lambda, \tau^I, \tau^C, \tau_s) = e^{I*}(\tau^I)$ and $q^{ccfd}(e^{ccfd}, \tau, \tau_s) = q^{I*}(e^I, \tau^I)$ hold, since this is the most efficient way of achieving the target emission level. Let us first recall the first order conditions under *CCfDs*. For readability purposes, we lighten the notation and let $q^{ccfd}(e^{ccfd}, \tau, \tau_s) \equiv q^{ccfd}$ and $e^{ccfd}(\lambda, \tau^I, \tau^C, \tau_s) \equiv e^{ccfd}$

In period 2:

$$p - \tau \cdot e^{ccfd} + (\bar{e} - e^{ccfd}) \cdot (\tau_s - \tau) = \frac{\partial C(q^{ccfd})}{\partial q} \tag{13}$$

In period 1:

$$\tau_s \left[\underbrace{\lambda q^I_{ccfd}(e, \tau^I, \tau_s) + (1-\lambda) q^C_{ccfd}(e, \tau^C, \tau_s)}_{\mathbb{E}[q^{ccfd}]} \right] = -\frac{\partial K(e^{ccfd})}{\partial e} \tag{14}$$

Where the period 1 expectation of (13) is (9). Since both $C(q)$ and $-K(e)$ are strictly convex and twice differentiable, then $\frac{\partial^2 C(q)}{\partial q^2} > 0$ and $-\frac{\partial^2 K(e)}{\partial e^2} > 0$. Therefore both $\frac{\partial C(q)}{\partial q}$ and $-\frac{\partial K(e)}{\partial e}$ are monotonically increasing and injective functions. If $\frac{\partial C(q^I)}{\partial q} = \frac{\partial C(q^{ccfd})}{\partial q}$ then $q^{I*} = q^{ccfd}$ and similarly, if $\frac{\partial K(e^I)}{\partial e} = \frac{\partial K(e^{ccfd})}{\partial e}$, then $e^{I*} = e^{ccfd}$. We now study under which conditions a *CCfD* can, or cannot, act as an implementation device for the incumbent government.

4.2.2 Can the incumbent implement $e^{I*}(\tau^I)$ and $q^{I*}(e^I, \tau^I)$?

The first case to consider is the intuitive one, where the government sets $\tau_s = \tau^I$ in period 1. In the event where it is still in power in period 2, it sets an effective tax rate equal to the strike price and the *CCfD* payments are null. Therefore, it follows from the expected period 2 first-order condition that $\mathbb{E}[q^{ccfd}] \geq q^{I*}(e^I, \tau^I)$ since positive expected *CCfD* payments generate an incentive to increase production and since

$q(e,\tau)$ is strictly decreasing in τ, where τ^I is the highest possible tax rate.

Going back to the period 1 f.o.cs, if the government sets $\tau_s = \tau^I$, we can deduce that since $\mathbb{E}[q^{ccfd}] \geq q^{I*}(e^I, \tau^I)$, then

$$\tau_s \left[\lambda q^I(e,\tau^I,\tau_s) + (1-\lambda)q^C(e,\tau^C,\tau_s)\right] \geq \tau^I \cdot q^{I*}(e^I,\tau^I)$$
$$\left[\lambda q^I(e,\tau^I,\tau_s) + (1-\lambda)q^C(e,\tau^C,\tau_s)\right] \geq q^{I*}(e^I,\tau^I)$$

Where the inequality is binding only if $\lambda = 1$, or if $\tau^I = \tau^C$, or both. This is equivalent to a case where there is no uncertainty and thus, is not of interest. We ignore that corner solution. For $\tau_s = \tau^I$,

$$\tau_s \mathbb{E}[q^{ccfd}] > \tau^I q^{I*}(e^I,\tau^I) \tag{15}$$

Accordingly, (15) implies that

$$\frac{\partial K(e^I)}{\partial e} < \frac{\partial K(e^{ccfd})}{\partial e}$$

Using the strict convexity of $-K'(e)$, we can conclude that $e^{ccfd}(\lambda,\tau^I,\tau^C,\tau_s) < e^{I*}(\tau^I)$

Proposition 4.1 *When the incumbent government sets the strike price τ_s equal to its certainty-optimal tax τ^I, the firm chooses its carbon intensity such that $e^{ccfd}(\lambda,\tau^I,\tau^C,\tau_s) < e^{I*}(\tau^I)$.*

From the incumbent's point of view, this result is not *ex-ante* optimal since the existence of expected positive *CCfD* transfers to the firm (in period 1) means that the firm will expect higher production in period 2, and as a result will over-invest in reducing its carbon intensity, as compared to the incumbent's optimal policy without uncertainty. Such an outcome holds because the size of the transfer strictly increases with effort $(\bar{e} - e)$. Therefore, regardless of who is in power in period 2, the fact

that e^I is not implementable naturally implies that a *CCfD* where $\tau_s = \tau^I$ never implements the incumbent's prefered allocation $(q^{I*}(e, \tau^I), e^{I*}(\tau^I))$. Note that this results relies on the assumption that the government has a unique optimal tax rate τ^I for both periods and that it does not manipulate it ex-post, once the investment in $e^{ccfd}(\lambda, \tau^I, \tau^C, \tau_s)$ is realized. In other words, the uncertainty is not about whether or not the incumbent government will implement what it promised, but rather on the fact that the firm doesn't know if it will still be in power in period 2.

We must therefore look for $\tau_s \neq \tau$. Clearly, it cannot be that $\tau_s > \tau^I$, because we have seen that when $\tau_s = \tau^I$, then $\tau_s \mathbb{E}[q^{ccfd}] > \tau^I q^{I*}(e^I, \tau^I)$ and it must be that $e^{ccfd}(\lambda, \tau^I, \tau^C, \tau_s) < e^{I*}(\tau^I)$. Therefore it follows that setting $\tau_s > \tau^I$ also yields $e^{ccfd}(\lambda, \tau^I, \tau^C, \tau_s) < e^{I*}(\tau^I)$, always.

Hence, let us assume $\tau_s < \tau^I$. Going back to the period 1 first-order condition, e^I is implementable if and only if

$$\begin{aligned} \tau_s \cdot \mathbb{E}[q^{ccfd}] &= \tau^I \cdot q^{I*}(e^I, \tau^I) \\ \tau_s \left[\lambda q^I(e, \tau^I, , \tau_s) + (1-\lambda) q^C(e, \tau^C, \tau_s)\right] &= \tau^I \cdot q^{I*}(e^I, \tau^I) \end{aligned}$$

Rearranging,

$$\tau_s = \tau^I \cdot \underbrace{\frac{q^{I*}(e^I, \tau^I)}{\lambda q^I(e, \tau^I, \tau_s) + (1-\lambda) q^C(e, \tau^C, \tau_s)}}_{<1} \tag{16}$$

Equation (16) generates important implications. First, notice that the denominator is a weighted average of production under *CCfDs* and a composite of two implicit functions of τ_s. Therefore, as both $q^I(e, \tau^I, \tau_s)$ and $q^C(e, \tau^C, \tau_s)$ are increasing in τ_s, that suggests a dampening effect: the more responsive output is to τ_s, the smaller the needed strike price. Second, for the equality to hold, it must be that $\lambda q^I(e, \tau^I, \tau_s) +$

$(1-\lambda)q^C(e,\tau^C,\tau_s) > q^{I*}(e^I,\tau^I)$, for any $\lambda \in (0,1)$. We know that in the case where $\tau_s < \tau^I$, then

$$q^I(e,\tau^I,\tau_s) < q^{I*}(e^I,\tau^I)$$

since when the incumbent is reelected, the contract's transfers are such that the firm has to pay the government for each unit produced. By incentive compatibility, it must accordingly be that

$$\tau^I > \tau_s > \tau^C \tag{17}$$

over a certain interval of reelection probability λ. This yields a trivial, yet important result. In a biparty system, the incumbent can credibly offer *CCfDs* only if its tax τ^I is more ambitious than the challenger's announced tax τ^C. Intuitively, for the firm to accept the contract, it must be that the probability of receiving payments is at least greater than zero. Hence, given τ^I and τ^C, we can identify a set of λ for which a strike price that implements $e^{I*}(\tau^I) = e^{ccfd}(\lambda,\tau^I,\tau^C,\tau_s)$ exists. Take

$$\begin{aligned}
\lambda q^I(e,\tau^I,\tau_s) + (1-\lambda)q^C(e,\tau^C,\tau_s) &> q^{I*}(e^I,\tau^I) \\
\lambda q^I(e,\tau^I,\tau_s) + q^C(e,\tau^C,\tau_s) - \lambda q^C(e,\tau^C,\tau_s) &> q^{I*}(e^I,\tau^I) \\
\lambda[q^I(e,\tau^I,\tau_s) - q^C(e,\tau^C,\tau_s)] &> q^{I*}(e^I,\tau^I) - q^C(e,\tau^C,\tau_s)
\end{aligned}$$

Which implies

$$0 < \lambda < \frac{q^C(e,\tau^C,\tau_s) - q^{I*}(e^I,\tau^I)}{q^C(e,\tau^C,\tau_s) - q^I(e,\tau^I,\tau_s)} < 1 \tag{18}$$

From $\tau^C < \tau^I$, the second period first-order condition signifies that the denominator

is positive. Hence,

$$q^C(e,\tau^C,\tau_s) - q^{I*}(e^I,\tau^I) < q^C(e,\tau^C,\tau_s) - q^I(e,\tau^I,\tau_s)$$
$$q^{I*}(e^I,\tau^I) > q^I(e,\tau^I,\tau_s) \tag{19}$$

Proposition 4.2 *There exists a set of* $\lambda \in \left(0, \frac{q^C(e,\tau^C,\tau_s)-q^{I*}(e^I,\tau^I)}{q^C(e,\tau^C,\tau_s)-q^I(e,\tau^I,\tau_s)}\right)$ *for which there are strike prices defined by* $\tau^I > \tau_s > \tau^C$*, such that the CCfD induces the incumbent's optimal carbon intensity* $e^{I*}(\tau^I)$

Equation (19) suggests that No combination of $\lambda, \tau^I, \tau^C, \tau_s$ simultaneously implements the incumbent's optimal level of production $q^{I*}(e^I,\tau^I)$ and its optimal carbon intensity level $e^{I*}(\tau^I)$. When the incumbent is reappointed, the existence of payments from the firm to the government reveal under-production, since those payments are a markup on the marginal production cost. Alternatively, when the challenger gains power, (17) and (19) indicate that

$$q^C(e,\tau^C,\tau_s) > q^{I*}(e^I,\tau^I) \tag{20}$$

Consequently, if the challenger wins the election, it sets $\tau^C < \tau_s$ and the government pays the firm for each unit produced. This is akin to a production subsidy and it results in over-production from the incumbent's perspective.

Proposition 4.3 *No combination of* $\lambda, \tau^I, \tau^C, \tau_s$ *simultaneously implements the incumbent's optimal level of production* $q^{I*}(e^I,\tau^I)$ *and its optimal carbon intensity level* $e^{I*}(\tau^I)$

Even in the absence of policy deviation, where the incumbent government would manipulate $\tau \neq \tau^I$ after the investment is made, we find that it is impossible to induce both the optimal carbon intensity level e^{I*} and the counterfactual certainty production plan q^{I*} through carbon contracts for difference.

5 The Optimal Strike Price

We now turn to the policymaker's problem. The objective is no longer to try to reproduce a first-best allocation, but to design a contract that maximizes expected welfare given the political and behavioral frictions described above. What changes here is the policymaker's perspective: rather than taking the firm's reaction functions as constraints in an implementation problem, we now view them as components of an endogenous equilibrium that defines welfare. This shift marks the transition from a purely positive analysis, showing how the contract operates, to a more normative one. In what follows, we characterize the optimal strike price that satisfies the second-best welfare maximization problem under uncertainty. As before, we remain agnostic about how *CCfDs* compare to other climate policy instruments.

Let the incumbent's social welfare function be defined as

$$W(e,q) = \underbrace{pq - \tau eq + (\tau_s - \tau)(\bar{e} - e)q - C(q) - K(e)}_{\pi} - \underbrace{\psi eq}_{\text{env. dmg}} + \underbrace{\tau eq}_{\text{tx. rev.}} - \underbrace{(\tau_s - \tau)(\bar{e} - e)q}_{\text{CCfD payments}} \tag{21}$$

The incumbent government takes the representative firm's profit into account, as well as environmental damages, carbon tax revenues and *CCfD* payments. In our model, the carbon tax and the *CCfD* payments are welfare neutral as they only act as transfers between the firm and the government. They do however have an effect on the firm's abatement and production decisions. We can therefore rearrange and simplify (21)

$$W(e,q) = pq - C(q) - K(e) - \psi eq$$

Expected welfare is thus given by:

$$\mathbb{E}[W] = \lambda \left[pq_I^{ccfd} - C(q_I^{ccfd}) - K(e^{ccfd}) - \psi e^{ccfd} q_I^{ccfd} \right] + (1-\lambda) \left[pq_C^{ccfd} - C(q_C^{ccfd}) - K(e^{ccfd}) - \psi e^{ccfd} q_C^{ccfd} \right]. \tag{22}$$

The government chooses τ_s, taking the firm's best-response functions $q(\tau_s), e(\tau_s)$ as given. We denote:

$$q_I(\tau_s) \equiv q_I, \quad q_C(\tau_s) \equiv q_C, \quad e(\tau_s) \equiv e,$$

and rewrite the objective:

$$\mathbb{E}[W] = \lambda \left[pq_I - C(q_I) - \psi e q_I \right] + (1-\lambda) \left[pq_C - C(q_C) - \psi e q_C \right] - K(e). \tag{23}$$

Differentiating with respect to τ_s, we obtain the first-order condition:

$$\frac{d\mathbb{E}[W]}{d\tau_s} = \lambda \left[(p - C'(q_I) - \psi e) \frac{dq_I}{d\tau_s} - \psi q_I \frac{de}{d\tau_s} \right] + (1-\lambda) \left[(p - C'(q_C) - \psi e) \frac{dq_C}{d\tau_s} - \psi q_C \frac{de}{d\tau_s} \right] - K'(e) \frac{de}{d\tau_s} = 0. \tag{24}$$

The first term in each bracket represents the welfare effect of increased output induced by a higher strike price. CCfD payments act like a subsidy, encouraging production; however, this gain is tempered by two elements: the marginal cost of production $C'(q)$ and the environmental externality ψe, both of which reduce the net benefit of additional output. The second term in each bracket reflects the marginal increase in environmental damages resulting from the induced change in abatement effort. As the strike price increases, the firm typically abates more (i.e., lowers e), but since total emissions are given by eq, more abatement shifts the environmental cost through both the changing intensity e and the level q. Finally, $-K'(e) \cdot \frac{\partial e}{\partial \tau_s}$ captures the technological cost of increased abatement: as the strike price rises, the

firm invests more in reducing emissions intensity, which is costly due to the convexity of the cost function $K(e)$. This term reflects the welfare loss from pushing firms to abate more aggressively than is socially optimal. Overall, the government faces a trade-off: raising τ_s reduces investment risk and increases expected abatement, but also leads to potentially excessive emissions and costly over-investment.

5.1 State-specific marginal welfare effects

It is useful to decompose the welfare derivative (24) as

$$\frac{dE[W]}{d\tau_s} = \lambda F_I(\tau_s; \lambda) + (1-\lambda) F_C(\tau_s; \lambda), \tag{25}$$

where each term represents the marginal welfare effect in one political state $\in I, C$:

$$F_j(\tau_s; \lambda) = (p - C'(q_j) - \psi e)\frac{dq_j}{d\tau_s} - (\psi q_j + K'(e))\frac{de}{d\tau_s}. \tag{26}$$

For each $j \in \{I, C\}$, define the *hypothetical marginal strike* $\hat{\tau}_s^j(\lambda)$ as any solution to

$$F_j(\tau_s; \lambda) = 0, \quad \text{for } j \in \{I, C\} \tag{27}$$

These benchmarks are *not* the optimal strikes in counterfactual economies where only state j matters. In such environments, the firm's abatement and output decisions would differ. Instead, $\hat{\tau}_s^j(\lambda)$ is a *derivative-based benchmark*: the strike at which the state-j contribution to the marginal welfare effect would change sign, evaluated at the true equilibrium responses $e(\tau_s)$ and $q_j(\tau_s)$.

5.2 Characterizing the optimal strike

The optimal strike solves the full first-order condition

$$F(\tau_s;\lambda) \equiv \lambda F_I(\tau_s;\lambda) + (1-\lambda)F_C(\tau_s;\lambda) = 0. \tag{28}$$

Under certain assumptions[3], $F(\tau_s;\lambda)$ is concave in τ_s.

Proposition 5.1 (Characterization of the optimal strike price) *For each $\lambda \in (0,1)$, let $\tau_s^*(\lambda)$ be an interior solution to*

$$F(\tau_s;\lambda) = \lambda F_I(\tau_s;\lambda) + (1-\lambda)F_C(\tau_s;\lambda) = 0, \tag{29}$$

Suppose that for each λ:

(a) $F(\tau_s;\lambda)$ is continuous and $F'(\tau_s;\lambda)$ is strictly decreasing in τ_s[4];

(b) $F_I(\tau_s;\lambda) > F_C(\tau_s;\lambda)$ for all τ_s.[5]

Then for every $\lambda \in (0,1)$:

1. *there exists a unique optimal strike $\tau_s^*(\lambda)$;*
2. *$\tau_s^*(\lambda)$ is weakly increasing in λ;*
3. *$\tau_s^*(\lambda) \to \tau_I$ as $\lambda \to 1$ and $\tau_s^*(\lambda) \to \tau_C$ as $\lambda \to 0$.*

By (a), $F(\cdot;\lambda)$ crosses zero at most once, so any interior solution is unique. Existence follows from the sign change: $F(\tau_C;\lambda) > 0$ and $F(\tau_I;\lambda) < 0$ (state I prefers a higher strike than state C), together with continuity.

[3] See appendix for the proof

[4] see appendix, where we show that this is true for quadratic costs

[5] Condition (b) follows from the fact that state I generates a higher carbon price than state C. An increase in τ_s moves the firm's behavior toward state I's policy and away from the policy preferred in state C.

For (2.), differentiate the identity $F(\tau_s^*(\lambda);\lambda) = 0$:

$$\frac{\partial F}{\partial \tau_s}(\tau_s^*(\lambda);\lambda)\frac{d\tau_s^*(\lambda)}{d\lambda} + \frac{\partial F}{\partial \lambda}(\tau_s^*(\lambda);\lambda) = 0. \tag{30}$$

Condition (a) implies $\partial F/\partial \tau_s < 0$, while (b) gives $\partial F/\partial \lambda = F_I - F_C > 0$. Hence $d\tau_s^*(\lambda)/d\lambda \geq 0$.

For (3.), as $\lambda \to 1$ we have $F(\tau_s;\lambda) \to F_I(\tau_s;1)$, whose unique zero is τ_I, so $\tau_s^*(\lambda) \to \tau_I$ by continuity; the case $\lambda \to 0$ and τ_C is analogous.

The results highlight that political risk enters the optimal contract in a disciplined way. An increase in λ raises the marginal welfare gain of increasing the strike price because it places more weight on the state in which higher emissions pricing is desirable. This effect operates entirely through the marginal welfare derivative and does not rely on corner solutions or discontinuous policy adjustments. As a consequence, small changes in political prospects lead to small changes in the optimal strike, reinforcing the interpretation of the *CCfD* as a stabilizing instrument.

Finally, proposition 5.1 abstracts from quantity-based constraints on firm behavior. The strike price influences output and abatement only through firms' optimal responses, and nothing prevents firms from expanding output when it is privately profitable to do so. This feature becomes important once production caps are introduced. In the presence of a cap, changes in the strike price may affect welfare both through price incentives and through the activation or relaxation of the quantity constraint. Section 6 explores how this additional margin modifies the characterization of the optimal strike and whether political uncertainty can justify the joint use of price and quantity-based instruments.

6 *CCfDs* with a cap on output

We now consider a case where the *CCfD* generates transfers until an output limit $\bar{q}$ is reached. The main intuition, which is widespread in the literature, is to revert to a benchmark that isn't directly tied to the firm's behavior so that the payment becomes less distortive (Schlecht et al., 2024; Newbery, 2023). A capped-output can be understood in multiple ways, each with different implications for efficiency and credibility. For instance, a natural benchmark would be setting the cap $\bar{q}$ at last year's (or period) production level to anchor transfers to a verifiable benchmark, while avoiding direct dependence on current firm behavior. This approach closely resembles "grandfathering" in emissions trading systems, where allowances are allocated based on historical output or emissions. Previous work on contracts for difference in the electricity market, notably by Schlecht et al. (2024) have proposed solutions for reducing distortions that arises when *CCfD* payments scale linearly with output. Another possibility is to set the cap in reference to an industry-wide average, so that $\bar{q}$ reflects sectoral rather than firm-specific activity. Such a design reduces the risk of rewarding firms with systematically higher output histories and has parallels in the literature on benchmarking allocation in the EU ETS (Neuhoff et al., 2012). Finally, one could adopt a declining cap over time, in line with long-run decarbonization trajectories, making $\bar{q}$ a dynamic function that tightens across contract years.

By tying compensation only to infra-marginal output, the cap introduces discontinuities in firms' expected revenue streams (Schlecht et al. (2024)). Third, historical or negotiated baselines used to set $\bar{q}$ can generate distributional inequities, advantaging incumbents with high past output while penalizing new entrants, as seen in grandfathering debates in emissions trading (Ellerman et al., 2010; Neuhoff et al., 2012). While these issues are important, we abstract from them in this paper.

A useful real-world reference point is provided by the recently introduced *Kli-*

maschutzverträge (climate protection contracts) in Germany. These contracts are explicitly designed to support deep decarbonisation investments in energy-intensive industries by compensating firms for the additional costs of low-carbon production relative to a conventional reference technology. In particular, compensation is not automatically proportional to realised output at the subsidised carbon price, but is instead tied to project-specific benchmarks, contractual volumes, and predefined eligibility criteria.[6]

At the same time, the German contracts are explicitly designed as an investment-triggering instrument rather than as a generic output subsidy. Contracts are awarded through competitive bidding and specify *ex ante* the eligible technology, reference emissions intensity, and the scale of production or emissions reductions covered by the agreement. Payments are thus conditional on the deployment and operation of a particular low-carbon process and are limited to a predefined contractual volume. This design reflects the policy objective of accelerating the adoption of specific decarbonisation pathways, such as green steel, low-carbon chemicals, or process electrification that would not be profitable even under anticipated future carbon prices, absent additional support. From the perspective of the model developed above, these institutional features can be interpreted as a deliberate restriction on the domain over which CCfD payments apply. By tying compensation to a benchmarked reference technology and capping the volume eligible for support, the contracts preserve the role of CCfDs as a commitment device that de-risks investment in low-carbon capital, while limiting the extent to which payments scale mechanically with realised output. In particular, they prevent firms from expanding production purely to increase transfers when the contractual strike price exceeds the market carbon price.

[6] see https://www.klimaschutzvertraege.info/startseite

6.1 The firm's problem with a cap on output

The representative firm now solves

$$\max_{e} \mathbb{E}\left[\underbrace{\max_{q\geq 0}\left(pq - e\tau q + \underbrace{(\bar{e}-e)(\tau_s-\tau)\min(q,\bar{q})}_{CCfD} - C(q)\right)}_{\text{period 2}} - K(e)\right] \tag{31}$$

Because the CCfD transfer saturates at $\bar{q}$, the optimality condition of the period 2 problem is now piecewise:

$$C'(q) = \begin{cases} p - e\tau + (\bar{e}-e)(\tau_s-\tau), & \text{if } q \in [0,\bar{q}), \\ p - e\tau, & \text{if } q \in (\bar{q},\infty). \end{cases}$$

The piecewise condition shows that the CCfD payment behaves like a per-unit markup on marginal revenue only up to the cap $\bar{q}$. When $\tau_s > \tau$, the pre-cap segment shifts the effective marginal revenue by $(\bar{e}-e)(\tau_s-\tau)$, modifying the production incentives. Once q reaches $\bar{q}$, the transfer ceases to grow with q; the marginal production condition drops to $C'(q) = p - e\tau$, which is (3). Geometrically, the case where $\tau < \tau_s$ is illustrated in figure 1, which shows a downward jump in the marginal revenue line at $q = \bar{q}$. The period-1 first order condition is

$$\begin{aligned} 0 &= \mathbb{E}\left[\frac{\partial \pi}{\partial e}(q^*(e,\tau);e,\tau)\right] \; - \; K'(e) \\ &= -\Big\{\lambda\big[\tau^I q^I + (\tau_s - \tau^I)\min(q^I,\bar{q})\big] \; + \; (1-\lambda)\big[\tau^C q^C + (\tau_s-\tau^C)\min(q^C,\bar{q})\big]\Big\} \; - \; K'(e), \end{aligned}$$

which we can rewrite compactly as

$$-K'(e) = \lambda\big[\tau^I q^I + (\tau_s-\tau^I)\min(q^I,\bar{q})\big] + (1-\lambda)\big[\tau^C q^C + (\tau_s-\tau^C)\min(q^C,\bar{q})\big]. \tag{32}$$

Equation (32) shows that the marginal return to abatement intensity (the reduc-

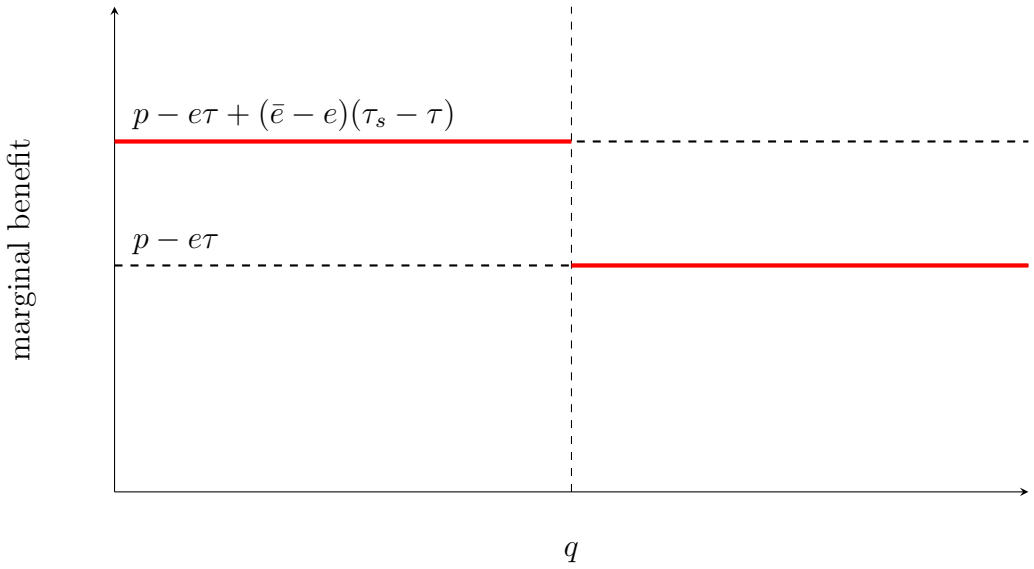


Figure 1: Optimality with a capped *CCfD*: the effective marginal benefit (MB) has a discountinuity at $q = \bar{q}$.

tion in per-unit emissions e) equals the expected reduction in tax payments plus the expected *CCfD* top-up evaluated at the minimum between the capped output and the actual output. Naturally, this is weakly increasing in the size of the cap. The first-order condition shows that the marginal value of abatement combines expected tax savings $\mathbb{E}[\tau q]$ with expected *CCfD* payments $\mathbb{E}[(\tau_s - \tau)\min\{q, \bar{q}\}]$. Intuitively, the government preserves compensations for infra-marginal units (up to $\bar{q}$), yet avoids affecting the full production output.

When the cap is non-binding, the marginal subsidy $(\bar{e} - e)(\tau_s - \tau_j)$ affects output directly, and

$$\frac{\partial q_j^*}{\partial \tau_s} = \frac{\bar{e} - e}{C''(q_j^*)} - \frac{\tau_s}{C''(q_j^*)} \frac{\partial e}{\partial \tau_s}.$$

When the cap binds, the direct term disappears and only the indirect effect via abatement remains:

$$\frac{\partial q_j^*}{\partial \tau_s} = - \frac{\tau}{C''(q_j^*)} \frac{\partial e}{\partial \tau_s},$$

The effective expected wedge is

$$\mathbb{E}[\omega_{\text{marginal}}] = (\bar{e} - e)[\lambda(\tau_s - \tau_I)\mathbf{1}\{q_I \leq \bar{q}\} + (1-\lambda)(\tau_s - \tau_C)\mathbf{1}\{q_C \leq \bar{q}\}]\,. \tag{33}$$

The capped contract generates asymmetric effects across states: it suppresses excessive output when carbon prices are low, and alleviates excessive contraction when prices are high.

6.2 Cap monotonicity and welfare effects

Let $m_j \equiv \min\{q_j, \bar{q}\}$ and $I_j \equiv \mathbf{1}\{q_j < \bar{q}\}$ for $j \in \{I, C\}$. From Section 5, expected welfare (net of transfers) with environmental damages is

$$E[W] \;=\; \lambda\,[pq_I - C(q_I) - \psi e q_I] \;+\; (1-\lambda)\,[pq_C - C(q_C) - \psi e q_C] \;-\; K(e), \tag{34}$$

while the period-1 first-order condition with a capped CCfD is

$$-\,K'(e) \;=\; \lambda\big[\tau_I q_I + (\tau_s - \tau_I)m_I\big] \;+\; (1-\lambda)\big[\tau_C q_C + (\tau_s - \tau_C)m_C\big]. \tag{35}$$

Differentiating (34) in τ_s and using the period-2 conditions yields the strike price first order condition

$$\begin{aligned} G(\tau_s;\bar{q}) \equiv \frac{dE[W]}{d\tau_s} &= \lambda\,(p - C'(q_I) - \psi e)\,I_I\,\frac{\partial q_I}{\partial \tau_s} + (1-\lambda)\,(p - C'(q_C) - \psi e)\,I_C\,\frac{\partial q_C}{\partial \tau_s} \\ &\quad -\;\big[\psi(\lambda q_I + (1-\lambda)q_C) + K'(e)\big]\frac{\partial e}{\partial \tau_s} \;=\; 0, \end{aligned} \tag{36}$$

with $\partial m_j/\partial \tau_s \;=\; I_j\,\partial q_j/\partial \tau_s$ and $p - C'(q_j) \;=\; e\tau_j$ if $I_j \;=\; 0$, and $p - C'(q_j) \;=\; e\tau_j - (\bar{e} - e)(\tau_s - \tau_j)$ if $I_j = 1$.

An increase in $\bar{q}$ affects $G(\tau_s;\bar{q})$ via: (i) the direct output channel I_j, which is weakly increasing in $\bar{q}$ (it can switch from 0 to 1 but not the reverse), thereby switch-

ing on the direct strike effect on q_j in state j; (ii) the abatement channel through m_j in (35), which raises (weakly) $\partial e/\partial \tau_s$ whenever a binding cap is relaxed, since $\partial m_j/\partial \bar{q} = 1$ locally.

For any strike τ_s, define

$$\bar{q}^*(\tau_s) = \max\left\{q_I^{ccfd}(\tau_s),\, q_C^{ccfd}(\tau_s)\right\},$$

the highest output the firm would choose in either state if production were unconstrained. If the cap satisfies $\bar{q} \geq \bar{q}^*(\tau_s)$, then it is inoperative: the firm optimally produces below $\bar{q}$ because its marginal cost is sufficiently high. Thus, the cap ceases to affect behavior at any level exceeding $\bar{q}^*(\tau_s)$, which depends on the curvature of $C'(q)$.

Proposition 6.1 (Monotonicity of the optimal strike price in the cap) *Let $\tau_s^*(\lambda, \bar{q})$ be any interior solution to $G(\tau_s; \bar{q}) = 0$, where $G(\tau_s; \bar{q}) \equiv dE[W]/d\tau_s$ is given in (36). If $\bar{q}' > \bar{q}$, then*

$$G(\tau_s; \bar{q}') \;\geq\; G(\tau_s; \bar{q}) \quad \textit{for every fixed } \tau_s.$$

Therefore the optimal strike price is weakly increasing in the cap:

$$\bar{q}' > \bar{q} \quad \Longrightarrow \quad \tau_s^*(\lambda, \bar{q}') \;\geq\; \tau_s^*(\lambda, \bar{q}).$$

If $\bar{q} \geq \bar{q}^*(\tau_s)$, the cap is slack in both states at the optimum, so the equilibrium allocation and $G(\tau_s; \bar{q})$ coincide with those in the no-cap problem:

$$G(\tau_s; \bar{q}) \;=\; G(\tau_s) \quad \textit{for all } \bar{q} \geq \bar{q}^*(\tau_s).$$

Remember that $G(\tau_s; \bar{q})$ is the marginal welfare effect of a change in the strike price. Raising $\bar{q}$ can only (i) turn on the pre-cap term by switching $I_j = \mathbf{1}\{q_j < \bar{q}\}$ from 0 to 1, which adds a nonnegative contribution to $G(\cdot)$; and (ii) increase m_j

where the cap binds, which raises the numerator in the expression for $\partial e/\partial \tau_s$, thereby (weakly) increasing the indirect effect of τ_s in $G(\cdot)$. Hence $G(\tau_s; \bar{q}') \geq G(\tau_s; \bar{q})$ at every τ_s, so the zero of $G(\cdot)$ cannot move left.

6.3 Welfare with a cap on output

The government now solves

$$\max_{\tau_s, \bar{q}} \mathbb{E}[W](\tau_s, \bar{q}), \tag{37}$$

This problem nests the benchmark without a cap; for any τ_s, choosing $\bar{q}$ large enough makes the cap inoperative and reproduces the uncapped allocation from section 5. To make this comparison explicit, define the value functions

$$V^{\text{no cap}}(\lambda) = \max_{\tau_s} \mathbb{E}[W](\tau_s, \infty), \quad V^{\text{cap}}(\lambda) = \max_{\tau_s, \bar{q}} \mathbb{E}[W](\tau_s, \bar{q}) \tag{38}$$

Because the capped problem allows the government to replicate the uncapped allocation by choosing an inoperative cap, welfare with a cap has to be at least weakly higher than that without. The more interesting question is therefore when the inequality is strict.

The cap affects welfare only when it binds in at least one state. When binding, the cap removes marginal units of output around $\bar{q}$. Whether this is desirable depends entirely on the social marginal benefit of those units, evaluated at the equilibrium induced by $(\tau_s, \bar{q})$. This observation leads to the following characterization.

Proposition 6.2 (Welfare effects of a production cap) *Let $E[W](\tau_s, \bar{q})$ denote expected welfare evaluated at the capped equilibrium induced by the policy pair $(\tau_s, \bar{q})$,*

and define the value functions

$$V^{\text{no cap}}(\lambda) \equiv \max_{\tau_s} E[W](\tau_s, \infty), \tag{39}$$

$$V^{\text{cap}}(\lambda) \equiv \max_{\tau_s, \bar{q}} E[W](\tau_s, \bar{q}). \tag{40}$$

Then the following results hold for all $\lambda \in (0, 1)$*:*

1. ***(Weak dominance)***

$$V^{\text{cap}}(\lambda) \geq V^{\text{no cap}}(\lambda).$$

2. ***(Strict improvement)*** *The inequality is strict if and only if, at the optimal uncapped strike* $\tau_s^{\text{no cap}}(\lambda)$*, there exists a state* $j \in \{I, C\}$ *and a level* $\bar{q} < q_j(\tau_s^{\text{no cap}}(\lambda))$ *such that the cap binds in that state and the social marginal benefit of output at the cap is negative:*

$$p - C'(\bar{q}) - \psi\, e(\tau_s^{\text{no cap}}(\lambda), \infty) < 0.$$

3. ***(Inoperative cap)*** *If* $(\tau_s^*(\lambda), \bar{q}^*(\lambda))$ *satisfies* $\bar{q}^*(\lambda) \geq \bar{q}^*(\tau_s^*(\lambda))$*, where* $\bar{q}^*(\tau_s)$ *is the threshold above which the cap never binds, then*

$$E[W](\tau_s^*(\lambda), \bar{q}^*(\lambda)) = E[W](\tau_s^*(\lambda), \infty),$$

and the optimal capped policy coincides with the uncapped one.

Proposition 6.2 clarifies the role of the cap as a genuinely distinct policy instrument. The cap cannot reduce welfare (when rationally chosen) because it enlarges the government's choice set. The key condition is the sign of the social marginal benefit at the discountinuity. If, under the optimal uncapped strike, the firm produces units for which marginal production costs and environmental damages exceed marginal benefits, then a binding cap raises welfare by truncating precisely those units

Finally, the comparison with the uncapped case clarifies the distinct roles played by price- and quantity-based instruments in this environment. The strike price affects welfare exclusively through firms' interior responses: changes in τ_s induce smooth adjustments in output and abatement via the firm's first-order conditions. By contrast, the production cap affects welfare only at the boundary, by truncating output in states where firms would otherwise produce beyond (below) a given threshold. As a consequence, political uncertainty by itself does not justify the use of a cap. When the optimal strike price alone ensures that all equilibrium output has positive social marginal value, the cap is optimally inoperative and adds no welfare gains. The cap becomes valuable precisely when the politically constrained strike price fails to eliminate socially inefficient output in some state—i.e., when there exists a range of production levels with negative social marginal benefit that cannot be ruled out through price incentives alone. In that case, a binding cap raises welfare by removing those residual units, complementing the strike price rather than substituting for it.

7 Discussion

7.1 Carbon intensity and the rebound effect

Our results demonstrate that contracts for carbon difference (*CCfDs*) can reduce the cost of uncertainty for clean technology investment, especially in politically unstable settings. By guaranteeing a minimum carbon price, *CCfDs* provide firms with revenue certainty, mitigating the policy risk that future governments may reverse or weaken carbon pricing regimes. However, this insurance function comes at a cost. In the event that the incumbent government loses power and its successor rolls back carbon pricing, the *CCfD* obliges the state to compensate the firm for the difference between the guaranteed and actual carbon prices. While this ensures investor protection, it also introduces a new form of distortion. If the firm continues to receive payments as though the carbon price were high — even though the actual carbon price is low

— it may have an incentive to increase output beyond the contract emitter's (the incumbent) optimum. This generates a rebound effect: the guaranteed revenue stream decouples production decisions from carbon externalities and decreases the marginal cost of production, resulting in higher production than would have occurred under the incumbent's original carbon pricing regime.

In essence, the *CCfD* stabilizes investment incentives but not emissions outcomes. Once the political environment shifts and the carbon price collapses, the firm still benefits from the shadow price embedded in the *CCfD*, but now faces lower marginal costs of production. Unless the contract includes quantity-based safeguards or regulatory constraints, the result is a level of production that exceeds what would be socially optimal under the previously higher carbon prices. This undermines the environmental integrity of the policy and raises questions about long-term climate effectiveness. This result introduces a fundamental intertemporal trade-off: *CCfDs* can align private investment with long-term decarbonization goals, but at the risk of locking in emissions trajectories that may become misaligned with future political realities. This suggests that *CCfDs* may be most appropriate when paired with additional mechanisms — such as production limits, performance standards, or clawback provisions — that could realign incentives in the event of major policy shifts. We do not explore these solutions, but think that they might be relevant for future work.

7.2 Political uncertainty, instrument design, and democratic constraints

The analysis highlights how political uncertainty shapes the design and performance of climate policy instruments in a democratic setting. In the absence of full commitment, future governments may revise carbon prices in response to electoral outcomes, creating policy risk for firms and weakening investment incentives. CCfDs mitigate

this risk by decoupling firms' effective carbon prices from realized political decisions. By fixing a strike price *ex-ante*, the government provides partial insurance against adverse political realizations while preserving some control over the future.

The strike price balances the welfare consequences of different political states, weighted by their likelihood. As a result, even when reelection is likely, the optimal strike generally remains below the incumbent's preferred carbon price, while still exceeding the opposition's preferred price when political turnover is likely. The *CCfD* therefore compresses the range of effective carbon prices faced by firms, reducing policy-induced volatility at the cost of persistent second-best distortions in each realized state.

By guaranteeing a fixed carbon price over a specified period, *Carbon Contracts for Difference (CCfDs)* provide long-term certainty for investors, thereby facilitating large-scale decarbonization projects. However, while their economic rationale is compelling — particularly in contexts plagued by political volatility or policy uncertainty — some might argue that *CCfDs* raise fundamental questions about democratic governance. Specifically, the binding nature of these contracts, which obligates governments to honor compensation schemes irrespective of future political shifts, may undermine the democratic principle that current governments should not constrain the policy space of their successors (Maskin and Tirole (2004); Besley and Coate (2001)). A central tenet of democratic accountability is the capacity of successive governments to adapt policies in accordance with evolving public preferences. Yet *CCfDs* impose long-term fiscal obligations that transcend electoral cycles, potentially limiting the space for future political change. Such guarantees effectively bind future administrations to fiscal responsibilities determined by their predecessors, regardless of subsequent shifts in public opinion or electoral outcomes. This arrangement raises concerns regarding democratic legitimacy, as future voters may find their policy pref-

erences constrained by decisions made in the past. This democratic deficit is further exacerbated by the delayed visibility of *CCfD*-related expenditures. Often, the fiscal implications of *CCfDs* — particularly in cases where market carbon prices fall far below the strike price — do not materialize until several years after the contracts are signed. This temporal disconnect makes retrospective accountability difficult. Citizens may bear the fiscal consequences of commitments they were not aware of, or did not support at the time of their inception. As emphasized in the literature on fiscal transparency and intertemporal policy design, such dynamics weaken the link between democratic will and budgetary outcomes (Persson et al. (1997)).

Moreover, the intertemporal nature of *CCfDs* raises issues of intergenerational equity. By committing future public funds to compensate private investors, present-day governments may reduce the fiscal flexibility available to future generations — precisely at a time when these generations may face new or more urgent climate, social, or economic challenges. The principle of intergenerational justice, central to both democratic theory and environmental economics, asserts that no generation should impose undue constraints on the policy autonomy or welfare of those that follow (Rawls (1971)). Insofar as *CCfDs* shift risk forward in time, they risk violating this principle. Indeed, in the absence of complementary institutional safeguards (e.g., parliamentary oversight, sunset clauses, or contingent escape options), such contracts could lock in spending patterns that crowd out future climate or social priorities (see Alesina and Tabellini (1990)).

Yet, the critique of *CCfDs* as "anti-democratic" relies on a narrow conception of democracy as policy reversibility. A more capacious view would acknowledge that democracy also requires institutions that credibly uphold prior democratic decisions, particularly when those decisions involve long-term societal goals. In this broader frame, *CCfDs* function as instruments of democratic continuity. They translate pol-

icy mandates — often resulting from democratic deliberation and electoral competition — into credible, durable commitments that survive beyond a single electoral cycle. In this sense, *CCfDs* enhance what might be called *ex-ante* democratic legitimacy. Their existence allows electorates to vote for climate ambition and have those preferences implemented, or at least get an allocation that is closer to those preferences, even in the face of later political turnover. The literature on time inconsistency and commitment in political economy provides useful parallels here. As Kydland and Prescott (1977) and more recently Harstad (2020) argue, political actors often lack the incentives or ability to implement policies with long-run payoffs, particularly when re-election incentives dominate. In such settings, commitment devices — including independent agencies, fiscal rules, or contracts like *CCfDs* — can help overcome this gap between stated preferences and actual outcomes. Without such mechanisms, electorates may find themselves repeatedly voting for climate action, only to witness policy reversals or implementation failures. This cycle erodes both policy effectiveness and citizen trust.

Moreover, *CCfDs* mitigate a distinct market failure: the hold-up problem that arises when private investors anticipate future policy reversal. By providing credible guarantees, *CCfDs* de-risk capital flows into clean technologies, therefore translating voter preferences for decarbonization into concrete infrastructure. In doing so, they align long-term societal objectives with private incentives, a core challenge in public economics. Ultimately, the democratic tension posed by *CCfDs* is not between commitment and accountability, but between different dimensions of accountability: responsiveness to evolving preferences versus responsibility to past mandates. Viewed this way, *CCfDs* are not inherently anti-democratic; they are a means of preserving democratic intent over time, in a political environment that is often short-sighted and institutionally fragmented.

From a policy perspective, our findings suggest that *CCfDs* should not be viewed as neutral financial instruments but as deeply political tools that redistribute risks across time and across governments. Their design must therefore account not only for technological cost curves and market dynamics, but also for the political economy in which they operate. This has implications for the optimal length, size, and fiscal treatment of CCfDs, as well as for complementary institutional safeguards, such as parliamentary oversight, sunset clauses, or flexible renegotiation mechanisms that can mitigate their rigidity without eroding credibility. We have avoided most of these issues, but we think that this is grounds for future work.

8 Conclusion

This paper studied how political turnover affects the design of Carbon Contracts for Difference (*CCfDs*) as instruments to promote investment under uncertain climate policy. We showed that while such contracts can mitigate the credibility problem that arises from electoral uncertainty, they cannot generally implement the incumbent government's preferred allocation. By guaranteeing a fixed strike price for carbon, *CCfDs* transform uncertainty about future policy into a contingent fiscal obligation. This mechanism can stabilize investment incentives, but the implied transfers act as subsidies that distort production and abatement decisions.

Our analysis demonstrated that the level of the strike price is central to this trade-off. For any chosen strike price, the contract alters both the firm's abatement and production decisions relative to the first-best outcome. A higher strike price strengthens the investment incentive but increases expected transfers and output distortions, while a lower strike price reduces fiscal exposure at the cost of weaker abatement effort. The optimal contract therefore balances credibility against fiscal cost: the strike price lies between the two parties' policy preferences and depends on the probability that the incumbent remains in office. Greater political credibility supports a higher

strike price and smaller expected transfers, whereas weaker credibility calls for more conservative terms. The strike price lies between the two parties' policy preferences and depends on the probability that the incumbent remains in office. Greater political credibility supports a higher strike price and smaller expected transfers, whereas weaker credibility calls for more conservative terms. We also showed that the structure of the contract itself affects efficiency. When payments apply to all units of output, firms expand production in low-price states, amplifying both fiscal exposure and emissions. Limiting payments to a fixed quantity of output disciplines this response without undermining the stabilizing effect on investment. Such a bounded design preserves the essential role of *CCfDs* in committing to a credible price path while containing the consequences of extreme policy outcomes. Taken together, these results imply that *CCfDs* can alleviate, though not eliminate, the commitment problem inherent in climate policy under democracy.

The paper deliberately abstracts from several important considerations. It does not compare CCfDs to alternative policy instruments, nor does it address issues of fiscal capacity, political commitment to honoring contracts, or strategic interactions between firms and governments beyond the representative-agent framework. These limitations point to natural extensions. Allowing for heterogeneous firms, endogenous political platforms, or explicit budget constraints could further clarify when CCfDs are desirable and how they should be combined with other climate policies. Overall, the results caution against viewing CCfDs as a frictionless solution to political uncertainty in climate policy. While they can play a useful role in sustaining clean investment under turnover risk, their design inevitably involves trade-offs between credibility and production efficiency. Understanding and managing these trade-offs is central to the effective use of long-term climate policy instruments in politically uncertain environments.

References

Acemoglu, D. (2003). Why not a political coase theorem? social conflict, commitment, and politics. *Journal of comparative economics*, 31(4):620–652.

Alesina, A. and Perotti, R. (1996). Fiscal discipline and the budget process. *The American Economic Review*, 86(2):401–407.

Alesina, A. and Tabellini, G. (1990). A positive theory of fiscal deficits and government debt. *The review of economic studies*, 57(3):403–414.

Besley, T. and Coate, S. (2001). Lobbying and welfare in a representative democracy. *The Review of Economic Studies*, 68(1):67–82.

Brunner, S., Flachsland, C., and Marschinski, R. (2012). Credible commitment in carbon policy. *Climate policy*, 12(2):255–271.

Chaton, C. and Metta-Versmessen, C. (2023). Le contrat carbone pour différences, un outil adapté pour la décarbonation de l'hydrogène? *Revue économique*, 74(5):705–737.

Chiappinelli, O. and Neuhoff, K. (2020). Time-consistent carbon pricing: The role of carbon contracts for differences.

Ellerman, A. D., Convery, F. J., and De Perthuis, C. (2010). *Pricing carbon: the European Union emissions trading scheme*. Cambridge university press.

Ewald, J., Sterner, T., and Sterner, E. (2022). Understanding the resistance to carbon taxes: Drivers and barriers among the general public and fuel-tax protesters. *Resource and Energy Economics*, 70:101331.

Federal Ministry for Economic Affairs and Climate Action (BMWK) (2022). The german carbon contracts for difference (ccfd) scheme. Accessed: 2025-01-10.

Gulen, H. and Ion, M. (2016). Policy uncertainty and corporate investment. *The Review of financial studies*, 29(3):523–564.

Harstad, B. (2020). Technology and time inconsistency. *Journal of Political Economy*, 128(7):2653–2689.

Harstad, B. (2024). Contingent trade agreements. Technical report, National Bureau of Economic Research.

Helm, D., Hepburn, C., and Mash, R. (2003). Time inconsistent environmental policy and optimal delegation.

Kalkuhl, M., Steckel, J. C., and Edenhofer, O. (2020). All or nothing: Climate policy when assets can become stranded. *Journal of Environmental Economics and Management*, 100:102214.

Kristiansen, T. (2004). Pricing of contracts for difference in the nordic market. *Energy Policy*, 32(9):1075–1085.

Kydland, F. E. and Prescott, E. C. (1977). Rules rather than discretion: The inconsistency of optimal plans. *Journal of political economy*, 85(3):473–491.

Maskin, E. (1999). Nash equilibrium and welfare optimality. *The Review of Economic Studies*, 66(1):23–38.

Maskin, E. and Tirole, J. (2004). The politician and the judge: Accountability in government. *American Economic Review*, 94(4):1034–1054.

May, N., Neuhoff, K., and Richstein, J. C. (2018). Affordable electricity supply via contracts for difference for renewable energy. *DIW Weekly Report*, 8(28):251–259.

Moore, J. and Repullo, R. (1988). Subgame perfect implementation. *Econometrica: Journal of the Econometric Society*, pages 1191–1220.

Neuhoff, K., Martinez, K. K., and Sato, M. (2012). Allocation, incentives and distortions: the impact of eu ets emissions allowance allocations to the electricity sector. In *Emissions Trading and Competitiveness*, pages 73–91. Routledge.

Newbery, D. (2023). Efficient renewable electricity support: Designing an incentive-compatible support scheme. *The Energy Journal*, 44(3):1–22.

Persson, T., Roland, G., and Tabellini, G. (1997). Separation of powers and political accountability. *The Quarterly Journal of Economics*, 112(4):1163–1202.

Postic, S. and Fetet, M. (2020). Global carbon accounts 2020. *IC4E Institute for Climate Economics. https://www. i4ce. org/publications-2*.

Rawls, J. (1971). *A Theory of Justice: Original Edition*. Harvard University Press.

Richstein, J. C. and Neuhoff, K. (2022). Carbon contracts-for-difference: How to de-risk innovative investments for a low-carbon industry? *IScience*, 25(8).

Rogoff, K. (1985). The optimal degree of commitment to an intermediate monetary target. *The Quarterly Journal of Economics*, 100(4):1169–1189.

Schlecht, I., Maurer, C., and Hirth, L. (2024). Financial contracts for differences: The problems with conventional cfds in electricity markets and how forward contracts can help solve them. *Energy Policy*, 186:113981.

Strausz, R. (2009). The Political Economy of Regulatory Risk. SFB 649 Discussion Papers SFB649DP2009-040, Sonderforschungsbereich 649, Humboldt University, Berlin, Germany.

Tirole, J. (1999). Incomplete contracts: Where do we stand? *Econometrica*, 67(4):741–781.

Williamson, O. E. (1975). Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization. *University of Illinois at*

Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship.

Appendix - Welfare Verification under Quadratic Costs

Let

$$C(q) = \tfrac{c}{2}q^2, \qquad K(e) = \tfrac{k}{2}e^2, \qquad c > 0,\ k > 0.$$

Under quadratic costs the firm's first–order conditions in states I and C take the form

$$p - \tau_j e + (\bar{e} - e)(\tau_s - \tau_j) = cq_j, \qquad j \in \{I, C\},$$

and the abatement condition is

$$\lambda(\tau_I q_I + (\tau_s - \tau_I)q_I) + (1 - \lambda)(\tau_C q_C + (\tau_s - \tau_C)q_C) = -ke. \tag{41}$$

All three equations are linear in (q_I, q_C, e), and their coefficients depend affinely on τ_s. Solving this linear system yields

$$q_j(\tau_s; \lambda) = a_j(\lambda) + b_j(\lambda)\,\tau_s, \qquad e(\tau_s; \lambda) = a_e(\lambda) + b_e(\lambda)\,\tau_s, \tag{42}$$

with coefficients a_j, b_j, a_e, b_e determined by $(c, k, p, \bar{e}, \psi, \tau_I, \tau_C, \lambda)$. No higher-order terms in τ_s arise because all equations are linear.

Substitute (42) into the welfare expression

$$E[W] = \lambda[pq_I - C(q_I) - \psi e q_I] + (1 - \lambda)[pq_C - C(q_C) - \psi e q_C] - K(e). \tag{43}$$

Since q_I, q_C, e are affine in τ_s and $C(\cdot)$ and $K(\cdot)$ are quadratic, the resulting expression is a polynomial in τ_s of degree at most two:

$$E[W](\tau_s; \lambda) = A_2(\lambda)\tau_s^2 + A_1(\lambda)\tau_s + A_0(\lambda), \tag{44}$$

A direct calculation shows

$$A_2(\lambda) = -\tfrac{c}{2}\big[b_I(\lambda)^2 + (1-\lambda)b_C(\lambda)^2\big] - \tfrac{k}{2}b_e(\lambda)^2 < 0, \tag{45}$$

because $c > 0$, $k > 0$, and the slopes b_I, b_C, b_e are nonzero except in trivial cases. Thus:

$$\frac{\partial^2 E[W](\tau_s;\lambda)}{\partial \tau_s^2} = 2A_2(\lambda) < 0, \quad \text{since } A_2(\lambda) < 0 \tag{46}$$

so welfare is strictly concave in the strike.