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Commentary

Carbon contracts for difference design: Managing carbon price risk in a low-carbon industry

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Introduction

Many countries apply emission trading schemes to operationalize their commitments under the Paris Agreement. However, current progress is slow and behind schedule to reach the 1.5°C target that was committed to. Especially in hard-to-abate sectors such as the steel, cement, and chemical sectors, investments are hampered because of their innovative nature. Projects of this nature depend on unproven technologies, such as green hydrogen, direct air capture, and carbon capture and storage, that inherently carry high risk. This raises the question of whether imposing a carbon price alone is sufficient to achieve climate ambitions or whether it should be complemented by other instruments.[1,2]

Somewhat counterintuitively, investments in zero-emission solutions for the hard-to-abate sectors carry carbon price risk, even though they do not emit greenhouse gases. This is because the carbon price remains present in their product market. The inability of innovators to hedge the carbon price risk in low-carbon projects hampers investment. Setting up de-risking tools would allow (partial) risk transfer from such investments to financial institutions or governments, allowing them to share the risk. This would aid said technologies in using conventional financing options. Unfortunately, long-term markets to hedge carbon price risk are limited, which could be due to liquidity constraints that limit the risk-taking ability of financial institutions.[3]

A carbon contract for difference (CCfD) is a policy instrument to address this market failure by mitigating carbon price risk, and it can provide a subsidy to developers of innovative projects to address the knowledge spillover market failure.[4] Simply put, the CCfD applies the concept of a contract for difference (CfD) to an emission trading scheme. Similarly to a CfD used to support renewable energy, different parties may bid into an auction for a minimum price guarantee (strike price), but a carbon price signal is used as the reference price instead of an electricity price index. The CCfD pays the developer of a decarbonization project the difference between the strike price, which may be defined in a tender, and the actual carbon price for the abated amount of emissions.

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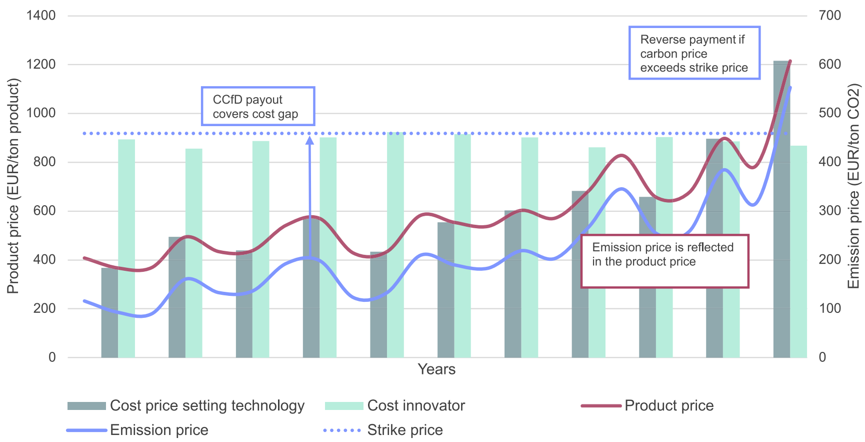

Figure 1. Concept of a CCfD
A CCfD pays out the difference between the strike price and carbon price, and as such, it aims to bridge the competitiveness gap of low-carbon technology and when conventional technology is price setting.

The use of electricity CfDs has been studied extensively.[5,6] However, that strand of literature is not directly applicable, as the hedge required when it comes to industrial investments is different than for a renewable electricity producer.[7] Electricity CfDs offer predictability in long-term revenues for an investor. For industrial investments, the problem is instead that their profitability depends on the carbon cost of their competitor; they require a hedge against a cost component of a competitor rather than a revenue stream of their own.

Previous research has studied the impact of CCfDs on project development financing and costs for policymakers[7,8] and found CCfDs capable of reducing financing costs by mitigating policy and market risks. A structured review of the definitions of contract design choices has been carried out, and different proposals are qualitatively compared.[9] The discussion is still ongoing on whether the coverage of a CCfD would need to go beyond carbon price risk and cover operational expenses as well, such as electricity prices. Implementations exist of a CCfD that dynamically adjusts the strike price to accommodate differences in operational costs compared to the price-setting technology.[10] However, it remains challenging to weigh the benefits of this additional risk transfer with the inefficiencies it causes.[11] For additional background on the CCfD concept, we refer the reader to the supplemental information.

While the concept of CCfDs is gaining traction as a tool to accelerate industrial decarbonization, e.g., in Germany,[11] their practical implementation raises important questions regarding contract design and effectiveness. Although CCfDs are primarily intended to mitigate carbon price risk, it remains unclear to what extent this risk is the primary barrier to investment compared to other factors, such as operational cost volatility or regulatory uncertainty. Furthermore, the challenge of setting appropriate benchmarks can significantly influence the competitiveness of low-carbon technologies relative to conventional ones. These design choices not only affect the risk exposure of investors but may also introduce inefficiencies if they extend beyond carbon price risk without clear economic justification.

The aim of this commentary is not to advocate for or against the use of CCfDs; rather, the article aims to clarify the functioning of a CCfD and make explicit how carbon price risk arises. We assess the impact of two critical design elements: coverage of operational cost risk and determination of the benchmark, which translates the production quantity into an amount of abated emissions. Some authors[4,10] propose to use the benchmark in the European Emission Trading Scheme (EU-ETS) at the time of investment. That approach is taken in the German implementation as well. In this work, we want to make more explicit how the selection of the benchmark influences the relative competitiveness of a low-carbon technology and the price-setting technology. We then go on to show the difficulties with selecting a benchmark.

Background on carbon price risk

Although carbon price fluctuations are inherent in emissions trading schemes, and risk models exist for firms with greenhouse gas emissions to effectively capture it,[12] the literature has yet to thoroughly address the exposure of low-carbon industrial investments to these fluctuations. Investors in such technology, hereafter referred to as innovators, also face carbon price risk, even if they do not emit greenhouse gases, because the carbon price is expected to be reflected in the price of the product they sell.

Consider how the operational costs of a zero-emission variant of a product compare to conventional technology, with and without support from a CCfD. For conventional technology, the price of the good is determined by its operational expenditure (OPEX) and the cost of emissions. Policies that shield firms from carbon price exposure (e.g., free allocation) can reduce the latter cost. Since the low-carbon technology has near-zero emissions, the difference in profitability between the innovator and conventional technology depends on the price of carbon (see Figure 1). The low-carbon variant is exposed to the carbon price even though it has near-zero emissions, hereafter referred to as carbon price risk.

A CCfD aims to address this via two mechanisms: mitigating carbon price exposure and providing a subsidy to bridge the competitiveness gap. The CCfD payout per unit produced is determined by the difference between the strike price and the carbon price, multiplied by a benchmark. This can be understood as comprising two components: a CCfD cost and a CCfD reward. The CCfD cost offsets the carbon price risk by imposing a financial obligation that balances the exposure to the carbon price. The CCfD reward provides a fixed remuneration per unit produced, which can cover the additional operational and capital expenditures of the low-carbon variant. In most cases, the CCfD reward exceeds the CCfD cost, resulting in a net subsidy (see Figure 1).

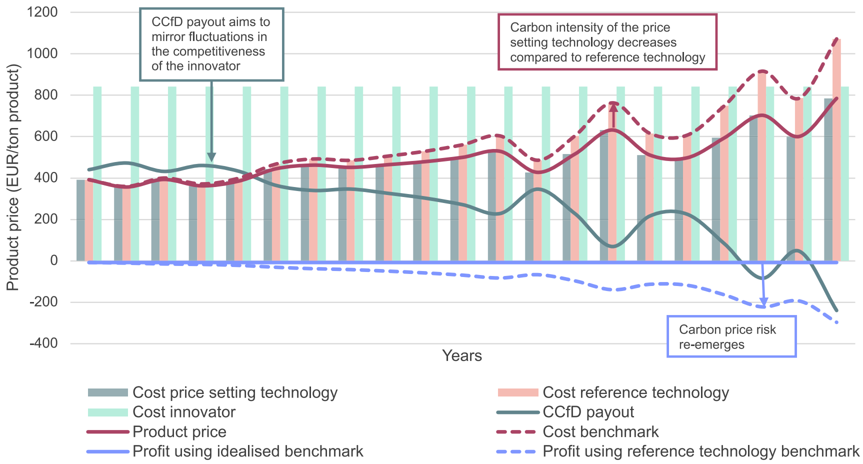

Figure 2. Carbon price risk re-emerges when the benchmark is no longer reflective of the actual carbon intensity

A CCfD tries to stabilize the revenue of the innovator by providing a payout that mirrors its competitiveness that depends on (1) the carbon price and (2) the carbon intensity of the product. Since a reference technology needs to be selected with a certain carbon intensity, while in reality, the carbon intensity of the price-setting technology fluctuates, carbon price risk will re-emerge in the revenue once the price-setting technology deviates from the reference technology (dotted line), compared to an idealized benchmark (solid line).

However, in some scenarios, the reverse may occur, leading to payments to the government. Employing such government-backed de-risking instruments does not remove the financial risk, but rather transfers it to policy makers.

Ability of a CCfD to mitigate carbon price risk

While it is clear that a CCfD can be used as a subsidy instrument, its ability to mitigate carbon price risk hinges on the design choices. The CCfD aims to derisk the profits of the innovator by providing a payout that mirrors its competitiveness that depends on (1) the carbon price and (2) the carbon intensity of the price-setting, competing production route. A reference technology needs to be selected with a certain carbon intensity as the emission benchmark, but in reality, the carbon intensity of the price-setting technology fluctuates, which makes this inherently hard to do. In Figure 2, we show how the revenue of the innovator will not be completely derisked when the current technology is used to determine the benchmark (no fluctuations in operational cost were considered here for clarification). Fluctuations in profits governed by the carbon price re-emerge once the price-setting technology deviates from the reference technology.

To fully mitigate carbon price risk, one would need to select the benchmark to be equal to the carbon intensity of the price-setting technology. Such an idealized benchmark would fully derisk carbon price risk and result in perfectly stable revenues if no other cost fluctuations are considered (see Figure 2). In practice, this cannot be achieved because the price setter is likely to change throughout the years. We show analytically in the supplemental information that a full mitigation of the carbon price risk is not possible with a pre-determined benchmark. Full carbon price mitigation would require a benchmark that decreases following the emission intensity of the price-setting technology, which is not practically possible since the emission intensity trajectory is not known at the time that the CCfD auction is held. One could attempt to identify the price-setting technologies through predetermined procedures and tie the emission benchmark to it, but this is rather impractical to anticipate by investors.

However, it shows that the degree of carbon price risk mitigation can be controlled by choosing the benchmark closer to the price setter or closer to the best available technology (such as the EU-ETS benchmark). Choosing the latter approach is questionable since the best available technology is expected to have a noticeably lower carbon intensity than the current technology, which is price setting. To maximally reduce carbon price risk, one would need to apply a reduction factor to the benchmark and aim to follow the decarbonization path of the considered product. This reduction factor would need to be set *a priori* so that investors can account for it when determining their bid; otherwise, it introduces a form of volume risk. Linking the reduction factor to external, widely recognized decarbonization pathways—such as the International Energy Agency Net Zero Emissions (NZE) scenario by 2050—could provide a transparent and consistent reference point.

Furthermore, there is the possibility that future high carbon costs will not be passed through to the end-product price (Figure 3). This could happen either due to regional policies protecting conventional industrial production or because an emission-free technology becomes price setting (not covered by a CCfD). This could occur, e.g., when emission prices rise and stabilize above the strike price; investments in the carbon-neutral variant should be viable without subsidy, leading the product price to disconnect from the carbon price. In this case, the CCfD-covered project would have the financial obligation to pay back the difference between the strike and carbon price, though it may not be able to pass through that cost in the market price of the product. Because of this, the innovator covered under the contract will again be exposed to the carbon price. It is important to ensure that the CCfD does not artificially push these investments out of the market if a new emissions-free price setter emerges. Note that this occurs whenever an emission-free technology becomes price setting, which does not necessarily mean the emitting technology is phased out completely.

This effect should be circumvented by ensuring that the contract duration is sufficiently short or by adding an appropriate clause in the contract. One could try to draw inspiration from electricity CfD design and place limits on the yearly or cumulative payout of the contract. Another solution would be to apply a reduction factor to the benchmark; this

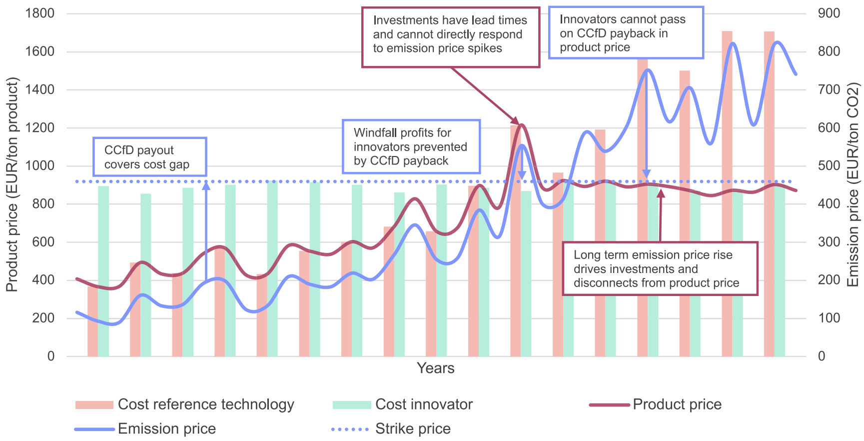

Figure 3. Reverse payments under the two-sided CCfD are only desired during short periods of price spikes

The pay-back obligation under a two-sided CCfD avoids windfall profits during short periods of price spikes in emission prices that are passed on into the product price. Long-term carbon price rises should drive investments and disconnect the product price from emission prices, leaving the innovators under a CCfD exposed to the carbon price due to pay-back obligation based on carbon price and carbon intensity of reference technology.

lowers the contract payout as time progresses, and as such, minimizes this effect. These approaches do not solve the fundamental problem with this effect—that no negative payments should occur once the product price disconnects from the emission price. The German implementation addresses this issue by allowing the contract to be irreversibly terminated with a 2-to-3-year notice period. The reasoning is that the innovator can foresee when competing technologies will become profitable, enabling them to terminate the support contract accordingly.

Empirical evidence shows that free allocation of emission allowances resulted in only partial pass-through of the carbon cost in the price of the product.[13] However, since the move to product-based benchmarks, all products receive free allocation equally, regardless of the production route. Hence, free allocation should, in principle, be accounted for as opportunity costs, and the relative competitiveness of the products should not be influenced. Even after the phase-out of free allocation, other regional policies might limit the exposure of producers to the carbon price, resulting in a partial carbon cost pass-through in the price of the product. If this is the case, the CCfD design should take this into consideration: since there is less carbon price risk present in such a case, the benchmark should be reduced accordingly. This further complicates the benchmark design and is similarly prone to ill selection.

Coverage of operational cost risk

The presence of risk in the operational costs of the innovators is put forward as a reason to intervene and cover those risks, as well, under a CCfD. Under given commodity prices and the market price of the product, the optimal CCfD price can be determined using, e.g., an auction process. However, any change in market conditions against which the entity cannot hedge may result in over- or undercompensation. A variant that covers operational cost risk could prevent changing market conditions resulting in over- or undercompensation by adapting the compensation level appropriately. This is, however, not essential in a CCfD, and whether or not to include coverage of operational risk is a political choice.

The question of how much risk a government should transfer remains. Surely, the excessive risk in these investments impacts projects' bankability, but the more risk that is transferred, the more inefficiencies that generally are induced.[11,14] Furthermore, the implications for governments that acquire the risk need to be considered as well. Care must be taken to ensure that innovators remain responsive to short-term fluctuations in prices to ensure responsiveness to changing economic conditions. This can be accomplished by adjusting the strike price on a low temporal resolution (e.g., yearly) but avoiding covering spot price fluctuations. Alternatively, the developer can complement a CCfD with a power purchase agreement (PPA), or a government can act as an intermediary that procures electricity through a CfD and resells it as a PPA to the developer. These approaches allow for risk transfer while retaining the economic incentives to efficiently schedule electricity use and build upon existing research on how to best set such instruments.[5,6,15]

Covering variable-cost risk might not be required at all in the CCfD design. In any case, participants in CCfD auctions can account for a risk premium in their bids to cover other sources of risk. Increasing their bid provides them with additional profit margin to cover potential increases in variable costs. Various participants have different risk profiles, and it is beneficial to have that reflected in the selection of the winning bids. Such a CCfD design—without OPEX risk coverage—could be more efficient, but it might not succeed in attracting participants because more risk remains with the investors.

Conclusion and policy implications

The CCfD aims to reduce carbon price risk by exposing the auction participant to a fixed carbon price rather than a fluctuating carbon price. However, a reference technology needs to be selected as a benchmark to govern how much carbon price risk will be transferred. The selection of this benchmark is rather difficult since it needs to be set *a priori*, while the actual amount of carbon price risk present might change throughout the contract. Furthermore, if the supply chain of a good is fully decarbonized before the CCfD ends, the CCfD-covered project would have the financial obligation to pay back the received subsidy, though it may not be able to pass through that cost in the market price of the product. This undesirable effect would increase uncertainty for investors and be contrary to the spirit of the instrument. One can try to circumvent the effect by ensuring the contract duration is sufficiently short or by adding an appropriate clause in the contract. One solution would be to apply a reduction factor to the benchmark; this lowers the contract payout as time progresses and, as such, minimizes this effect. Another solution is to add limits on the payback. Nevertheless, these partial solutions do not alter the conclusion that carbon risk cannot be fully mitigated through a CCfD.

Covering operational expenses through a CCfD should be considered with caution for the possible adverse effects it could have on the incentives of firms. Care must be taken to ensure that producers remain responsive to short-term fluctuations in commodity prices. This can be done by adjusting the support only yearly without directly covering spot price changes. If deemed necessary, we recommend considering complementing a CCfD with existing hedging instruments instead of covering OPEX expenses through the CCfD. Further developing long-term futures and private PPAs for electricity may reduce the need to cover such expenses in a CCfD.

Quantitative research on the risk-mitigating ability of CCfDs is still lacking but is required to ensure an efficient roll out of this novel mechanism, if deemed necessary. In particular, future work should aim to quantify the magnitude of unhedgeable carbon price risks across different sectors and technologies, assessing the extent to which existing market instruments (such as forward contracts, futures, or PPAs) can effectively hedge these risks. This would help determine whether the residual risks are significant enough to warrant modifications to CCfD design or if the simply "carbon price risk only" contract structure suffices. Additionally, further investigation of essential design options is needed, such as the implementation of pay-back-obligation protection mechanisms and strategies for managing deviations from anticipated production quantities. Another suggestion for future work is to study how a CCfD affects governments, who have to find a way to deal with the risk they acquire if they implement such instruments.

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AUTHOR CONTRIBUTIONS

Conceptualization, A.H. and K.B.; modeling, A.H.; analysis, A.H.; writing – original draft, A.H.; writing – review, K.B. and E.D.; supervision, K.B. and E.D.

DECLARATION OF INTERESTS

The authors declare no competing interests.

SUPPLEMENTAL INFORMATION

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