How to deal with risks of carbon sequestration within an international emission trading scheme

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Abstract

We address how carbon capture and sequestration (CCS) should be embedded in an international emissions trading scheme. We describe the intertemporal aspects of Carbon Sequestration Bonds (CSB) that we had formerly suggested as incentives for profit-oriented firms and investors to use only sites with a reasonable low leakage rate. CSB shall also support long-term liability rules for an optimal allocation of risks. We would allow to trade options on the bond beforehand, thereby making the security of formations subject to the investigative power of free markets and providing early-on liquidity to companies that are able to establish trust in their formations. We outline two versions of CSB. Both implicitly presuppose perfect capital markets and time consistent behavior of the regulatory authority. In particular, it is also assumed that all relevant information about risks, site quality and prices are accessible to all market agents. Here we stress that investment in reliable pilot projects for CCS may overcome potential time inconsistent behavior as a prerequisite for well-functioning regulatory system using the investigative power of markets. Moreover, the proposed framework allows for a more realistic assessment whether markets and regulatory authorities are able to ensure long-term liability.

Keywords: CO_2, carbon capture and sequestration, uncertainty, bonds, market solution, liability, market imperfections

Introduction

The option of capturing CO_2 at large power stations and storing it in geological formations (CCS) allows for the use of fossil energy resources without further destabilization of the climate system. If backstop-technologies such as renewable energy sources are high-cost options it may be reasonable to temporarily use end-of-pipe technologies like CCS [1,2]. However, CCS is a risky option for three reasons: First, CO_2 may outgas from geological deposits and therefore may harm the climate system further [3]. Second, underground CO_2-migration may cause undesirable regional side-effects; e.g. invading into freshwater reservoirs. Third, CCS may induce economic risks because it postpones investments in backstop-technologies like renewable energy sources and hence may prevent the reduction of costs of the backstop-technologies by technological

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change. The first two types of risk root in potential leakage. Economists have proposed environmental performance bonds [4-5] in order to guarantee safe-minimum standards. Here we describe CSB in terms of two incentive schemes that would allow to get a market-based handle on the intertemporal aspects of uncertain leakage rates.

This paper is organized as follows. In part 2 we describe two versions of our CSB proposal. In part 3 we discuss the problem of perfect capital markets and the capability to commit to reliable emission reduction schemes. We argue that liquidity constraints because of imperfect capital markets, bubbles on the secondary market and time inconsistencies induced by incredible commitments of political authorities are limits to CCS bonds. We also discuss possibilities to overcome these shortcomings.

Carbon Capturing and Sequestration an option to buy time or to waste time?

CCS is an option to buy time when opportunity costs of CCS are equal to the social cost of carbon [2]. Uncertain leakage rates are problematic if they have not been internalized in schemes – either market-based or regulatory – that would aim at a meaningful share of mitigation options. The following two schemes shall provide such internalization.

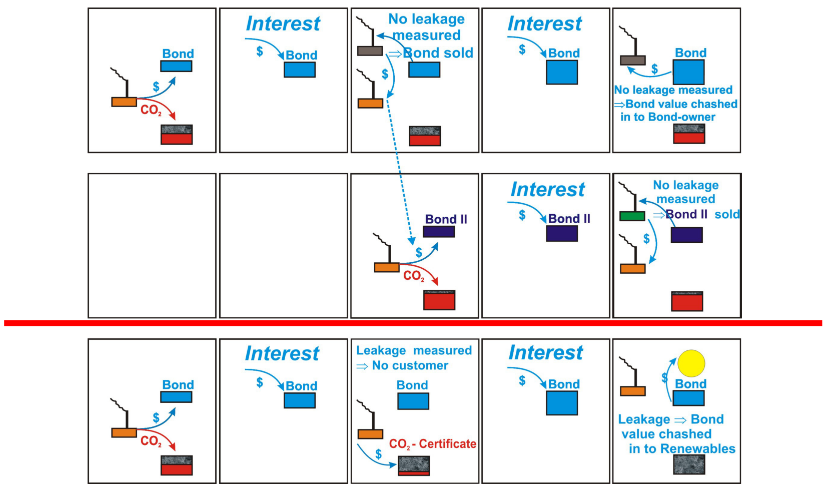

Figure 1: CCS bond scheme #1. A company is required to buy a bond proportionally to the amount to be sequestered. The bond price is fixed apriori. In case the formation is found dense, the bond is handed back with market interest. If the formation appears trustworthy an option on the bond can be traded in advance providing early liquidity to the company thereby making the security of the formation subject to the investigative power of the markets. Top & center movie (spanning a couple of decades): secure formation, bottom graph: leakage.

Proposal #1: Carbon Sequestration as a joker if other mitigation options fail

Leaking carbon dioxide would not be a catastrophic event for the climate, as long as no large amounts of carbon dioxide leak from all formations simultaneously. The following considerations always presuppose that global unexpected leakage does not occur.

Although the probabilities of such damage are not (yet) known, some safe-minimum standards could be defined which provide the basis for the calculation of the bond price. As carbon dioxide leaks from a geological formation, the atmosphere is used for its storage without a price having previously been paid. Therefore, the company has to buy a permit for the use of the atmosphere in case carbon dioxide should leak. However, this mechanism alone will not prevent mismanagement in carbon dioxide sequestration. The management of a company could count on decreasing permit prices in the long run, or just assume that another management will have to deal with the damage later. Whenever the time frame of investors is shorter than the time assumed for carbon dioxide to leak, and whenever they are willing to take high risks, the storage of carbon dioxide in geological formations will always be the preferred option of investors because the risks can be shifted upon later generations. It is therefore crucial to create incentives for companies to store carbon dioxide in formations as safely as possible in the first place, and for them to do so in their own self-interest.

According to our CSB scheme, every company that plans to store carbon dioxide in geological formations has to buy bonds (see Fig. 1) that equal the disutility induced by CCS (which are the not internalized costs of private enterprise). From the point of view of the firm this bond is an asset. For the transmission time of the bond, the company guarantees that all carbon dioxide will remain within the geological formations. If this really happens to be the case, the company will receive interests on the bond – equal to a long-term security. The company is allowed to sell the bond on the market during the transmission time. After the transmission time the owner of the bond has to prove to some kind of environmental authority how much CO_2 has remained underground. For the leaked fraction of carbon dioxide, the bond is partially devalued, the owner has to partially depreciate the claims to the environmental authority, and in addition, the owner or the company has to issue a CO_2 emission certificate. The net amount paid to the environmental agency has to be used for subsidizing renewable energies. These subsidies are paid as a compensation for the competitive disadvantage of the renewable energies. Companies will only be able to sell their bonds when they can offer buyers better interest rates than a non-risky security. Therefore, an incentive is created for the entire energy sector not to undermine trust in the bonds. The threat of a devaluation of bonds makes the safety of geological formations a marketable good.

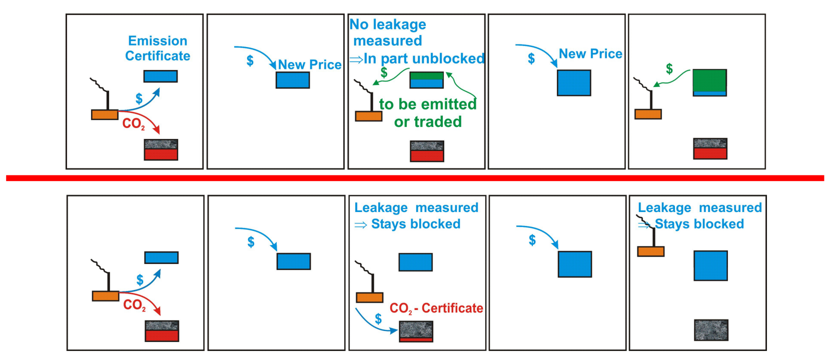

Figure 2: CCS bond scheme #2. As a key difference compared to scheme #1, initially, the company has to buy an emission certificate as if it were to emit to the atmosphere. Hence the bond – version 2 – price equals the CO_2 price. Over time, the worst-case end of the leakage rate error bars may shrink. Each year, an according fraction of the certificate is declared as a "certificate of secure sequestration", and additional "fresh" emission certificates will be handed over from the authority for free. That way, the authority does not have to decide on bond prices and if formations leaked much more than initially expected world wide, the climate goal could still be observed. As in scheme #1, an option on the bond could be traded in advance. Top movie: secure formation, bottom: leakage.

Proposal #2: CCS-bonds as special emission permits

Our second proposal imposes a global emission cap under unknown leakage rates (and mimics the first proposal otherwise). It therefore makes the CCS-bonds automatically part of the emission certificate scheme. For carbon to be sequestered, "quasi atmospheric emission permits" have to be bought, as it is not clear yet to which degree the geological formation is leaking.

However, this certificate is not devalued as in the truly atmospheric emission case, but it is just "blocked" as long as it is not proven which fraction of the carbon will stay underground. Once the worst cases of leakage rate have been excluded by experience over time ("glide path that is below the level of concern" [3]), for that amount accumulated over time that seems to be safely deposited, iteratively a fraction of the initial emission certificate becomes unblocked by the state and can be sold again. In case of a secure formation, finally all of the certificate could be used for atmospheric emissions. As the CCS-company can expect an increasing emission certificate price, it has an incentive to eventually perform CCS, particularly into those formations that have a high chance to be dense.

To conclude, in proposal 2 the guardrail on emissions is set to first priority. The effects of the uncertainties are shifted onto global mitigation costs, in case leakage cannot be excluded quickly enough or the price for emission permits becomes too high for a well-functioning economy.

Limits to CCS Bonds

Liquidity Constraints

Both models implicitly assume that capital markets are well functioning. In particular they assume that there are no liquidity constraints imposed on firms intending to sequester carbon in geological formations.

In proposal #1, the liquidity constraint has potentially a twofold impact on firm's decision to undertake CCS: First, banks may be reluctant to offer credits for buying the required bonds when they overestimate risks. Therefore, the risk premium for CCS increases above the market interest rate. Second, firms may find it difficult to sell bonds on the secondary market when market agents are also very risk averse. In both cases, the liquidity constraint is imposed on CCS firms because of informational asymmetries: Neither banker nor venture capitalists are able to assess and to monitor different sequestration options. However, they assume that CCS firms have private information about sites and sequestration technologies which are not public and therefore not accessible to all market agents.

In proposal #2, the liquidity constraint is also relevant because the value of emission allowances is uncertain dependent on the yet uncertain leakage rate. Credits used for buying these allowances can also be limited by banks or venture capitalists when they judge the risk as too high. Also the secondary market of allowances depends on the risk perception of the different agents.

It seems for improving the regulatory framework, a changed information structure is crucial for any institutional design. Therefore, the task of public authority is as follows. They should launch pilot projects and implement reliable monitoring systems that would not add significantly to the overall costs of CCS [7]. The relevant information gained from such pilot projects about sites and technologies should then be provided to the public. Under the condition that private information become public, the bond scheme acts more efficiently on leakage rate uncertainty than any single bureaucratic institution with their standard instruments (allowances, taxes, subsidies) could achieve: When imposing an optimal tax on different sequestration technologies and/or sites, the regulatory authority would have to use and collect all the relevant information. In the case of a bond system, the regulatory authority simply has to define an appropriate average leakage rate – nothing more because there is an incentive for market agents to use all the relevant information about sequestration technologies and sites attributes. Even if markets are only weakly efficient, they will do a better job in information gathering and distribution as the potential single bureaucratic institution.

Irrational Exuberance and social herd effects

It is a well known fact, that information can only be used in an efficient way if markets are robust against social herd effects. However, at the bond markets the traded goods are expectations about risks. In the case of hard uncertainty, it is likely that agents will not only gather information according to their own private cost-benefit analysis but they will observe each other in order to form their opinions about the risk of CCS. At the very early stages, when the risks are unknown, most investors are keen to invest in CCS because the potential risks may occur far in the future. However, if it turns out that investors have been overconfident, bonds on the secondary market will be devalued, and other sectors have to reduce their emissions. The CCS sector externalizes its social costs to other sectors. The social herd effects induce economic risks on the secondary market of bonds. However, a breakdown of the secondary market could also put pressure on the regulatory authority to relax the emission cap. In that sense, social herd effects may induce also ecological risks. Therefore, the question whether regulatory authorities are capable for time consistent commitments or not is crucial for a realistic assessment of any market design.

Time Inconsistencies

The capability for time consistent commitments is crucial for the design of cap and trade systems as a whole. If it turns out that CCS is a too risky option, the development on secondary bond markets may create a strong incentive either to relax or to strengthen emission caps. If secondary bond markets have underestimated the risks, there is a strong incentive for them to relax emission caps. If it turns out that CCS works well, there is tendency to implement more ambitious emission reduction schemes. Both cases cause some time consistency: In the first case, investors may anticipate that regulatory authorities will relax emissions and therefore will invest too less in CCS. In the second case, there is too much investment in CCS because investors anticipate the risk of higher emission reductions which makes CCS more profitable. The bond market's time horizon is not able to guarantee long-term liability. However, it should be noted that the bond market is not implemented to ensure long-term liability.

The long-term liability of sequestration sites is a public good. Therefore, there must be a lender of last resort ensuring liability for leaking sites. This lender of last resort needs the authority to adapt the emission according to the leakage rate. Some authors are quite skeptical that nation states or other international governance structures are able to time consistent commitments. However, most of the skeptics underestimate that regulatory authorities have to invest in their reputation to ensure long-term commitments – monetary policy and the struggles against inflation are widely known policy fields where investors believe in long-term commitment of public authorities. It is obvious that a public authority cannot commit itself for the next hundred years in reliable way. However, the public authority can invest into a path dependent transformation process. Such an investment could be public spending in CCS projects. Such investments show market agents that the regulatory authority is committed to ambitious emissions reductions and low leakage rates. The bond market and emission trading scheme has to be complemented with a reliable R&D policy in capturing and sequestration.

Conclusion

We have discussed intertemporal aspects of two bond-based regulatory frameworks (CSB) that we had previously suggested as market-based tools to internalize leakage rate uncertainties. This type of hard uncertainty demands the start of a learning process about new emerging ecological and economic risks. We have discussed CSB in view of three crucial market imperfections – asymmetric information, social herd effects and time consistency as crucial requirements for an efficient regulatory framework: Regulatory authorities have to invest in pilot projects for CCS proving best practices for capturing and sequestering carbon. In this context it is seen as an investment in a reliable commitment. The effect of this investment is threefold: a) It makes information publicly available which is a prerequisite for well-functioning bond and/or emission trading markets, b) the public available information prevent markets from social herd effects and c) it ensures time consistent behavior. These are prerequisites for CSB.

We have proposed two different permit schemes designed in such a way that safe deposits are preferred and uncertainty about leakage is actively reduced by CCS-companies. In proposal #1 CCS is considered as a joker if other mitigation options fail from an economic point of view. Proposal #2 is designed in order to avoid the ecological worst-case scenario that the leakage rate of geological formations is much higher than expected. However, these two proposals should not be seen as contradictory because both have the potential to merge to a hybrid version. In the very beginning, only small-scale experiments will be launched with relatively low environmental risks on a global scale. Therefore, for small-scale experiments proposal #1 could be appropriate because it encourages investors to undertake CCS-investments. If CCS become a large-scale option proposal #1 could be transformed to proposal #2 which set the guardrail on emission to first priority. Both permit schemes would have to be extended in order to internalize environmental risks of CCS beyond CO_2 leakage as well.

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