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ETCLIP – The Challenge of the European Carbon Market: Emission Trading, Carbon Leakage and Instruments to Stabilise the CO2 Price

Price Volatility in Carbon Markets: Why it Matters and How it Can be Managed

Claudia Kettner, Daniela Kletzan-Slamanig, Angela Köppl, Thomas Schinko, Andreas Türk

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Price volatility in carbon markets – Why it matters and how it can be managed

A report for the project ETCLIP "The Challenge of the European carbon market – emission trading, carbon leakage and instruments to stabilize the CO_2 price"

Claudia Kettner, Daniela Kletzan-Slamanig, Angela Köppl, Thomas Schinko, Andreas Türk

May 2011

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Executive Summary

There has been an extensive scientific discussion focussing on the optimal instrument choice to control emissions. In economic theory market-based instruments like taxes or emissions trading are advocated over command-and-control regulation because they ensure not only environmental effectiveness but also economic efficiency, i.e. emission reductions are reached at lowest costs. Given the necessity to reduce carbon emissions in order to limit climate change emissions trading was chosen as policy instrument by the European Union and was also proposed in the United States. Its advantages were seen primarily in the certainty of the quantitative target, i.e. environmental effectiveness, and furthermore in its political feasibility.

The environmental effectiveness of an emissions trading system, i.e. the achievement of a certain emission reduction target, depends on the one hand on the stringency of the cap and on the other hand on the scheme's ability to provide stable regulatory conditions and incentives for investment in emission saving technologies. However, in case of highly volatile CO_2 prices no clear investment signal is provided and hence firms' decision making and planning is rendered difficult. Price volatility can e.g. result from institutional factors such as changes in the stringency of the cap or from economic fluctuations, changes in fuel prices or weather conditions or developments of fuel switching possibilities. Analyses of price developments in the European Emission Trading Scheme (EU ETS) indicate that in Phase 1 (2005 – 2007) fluctuations were mainly caused by incomplete information at the beginning, adjustments after the emergence of verified emission data and regulatory mechanisms. At the beginning of Phase 2 (2008 – 2012) in contrast a decline in carbon prices was observed as firms sold surplus allowances resulting from lower emissions due to economic recession. For Phase 3 of the EU ETS (2013 – 2020) hence the introduction of price stabilisation measures has been suggested by several Member States during the discussions on the EU energy and climate package.

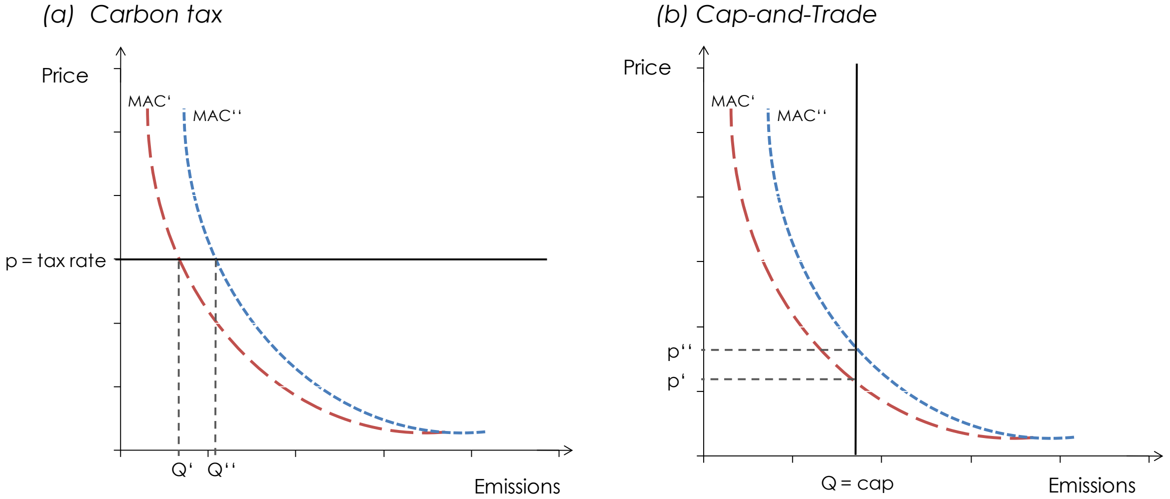
Various instruments can be integrated in a cap-and-trade scheme in order to reduce price volatility such as provisions for banking and borrowing, the approval of offsets for compliance purposes and hybrid systems, i.e. combinations of price and quantity mechanisms. Given the long-term nature of climate policy, the related uncertainties regarding technological change and political frameworks, and given a rising speculation in carbon markets, such price stabilisation approaches should be considered for the future design of emission trading schemes.

1 Introduction

There has been an extensive scientific discussion focussing on the optimal instrument choice to control emissions. In economic theory market-based instruments like taxes or emissions trading are advocated over command-and-control regulation as they ensure not only environmental effectiveness but also economic efficiency, which means that emission reductions are reached at lowest costs. Abatement activities will be carried out as long as the price of an emission allowance or the tax rate is higher than marginal abatement costs. Furthermore, flexibility for regulated entities compared to e.g. a fixed technological standard is provided for.

In the case of a carbon tax, the price of CO_2 emissions is determined by the regulator whereas the quantity of emissions follows from abatement activities, given firms' adjustments to the regulation and their respective marginal abatement costs[1]. In the case of tradable emission permits, the quantity of emissions is determined by the regulator, while the price for emissions is formed on the market by demand and supply of emission permits. Supply is determined by the overall cap on emissions while demand depends on the firms' respective marginal abatement cost functions (Metcalf, 2009; see also Figure 1 (a) and (b)).

Figure 1: Price and quantity instruments for emission reductions



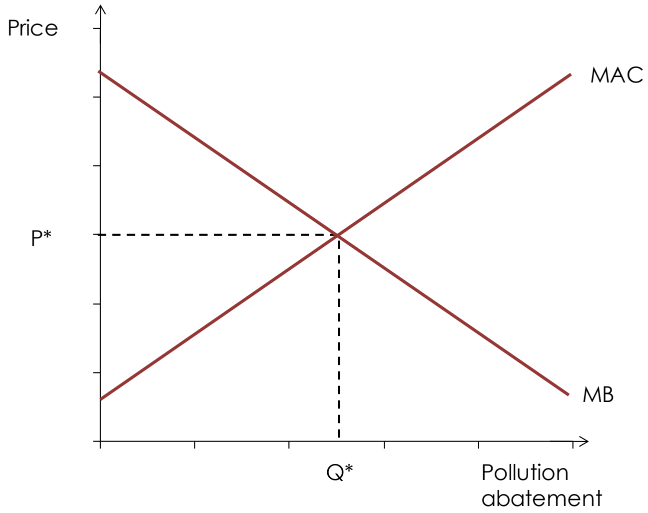
Source: Own illustration, based on Wood – Jotzo (2011), Murray et al. (2009).
The curved dotted lines represent alternative marginal abatement cost curves (MAC' = cheaper abatement, MAC'' = more costly abatement); the solid line represents the carbon price for the two policy options. The intersection of the curves gives the resulting emission level and price. In case of a carbon tax (a) the price for carbon emissions is fixed, but the level of emissions changes depending on the abatement cost curves. In an emissions trading scheme (b) the level of emissions is determined but the resulting carbon price varies.

According to economic theory, either approach would deliver the same outcome. This is indicated in Figure 2 by the intersection of the marginal abatement cost (MAC) and the

[1] Emissions are adjusted until the tax rate is equal to marginal abatement costs.

marginal benefit (MB) curve at P* and Q*. This rationale would presuppose a world without externalities and uncertainty, i.e. perfect information, rational agents and the absence of market failures (McKibbin – Wilcoxen, 2002, Hepburn, 2006).

Figure 2: The social optimal level of pollution abatement



Source: Mason (2009)

However, in the real world numerous uncertainties exist that affect the efficiency and effectiveness of emission control instruments. These include:

- The definition of the “right” emission level.
- Insufficient knowledge about abatement costs and asymmetries of information between regulator and firms regarding abatement costs and technological options.
- The future development of energy prices, technology costs, innovation and economic growth.
- Uncertainties about the stability of regulation.

Weitzman (1974) showed that under uncertainty of marginal abatement costs and marginal benefits the outcomes of taxes and permits are not equivalent, and that furthermore the relative slopes of the curves determine the ultimate outcome of the policy. Therefore, both market-based instruments – taxes as well as emissions trading schemes (ETS) – have advantages and disadvantages depending on the respective market characteristics and uncertainties; policy-makers have to decide whether the uncertainty about prices or about quantities represents the greater burden to society (Murray et al., 2009).

The European Union as well as other countries such as the United States or Australia opted for or discussed an emission trading system to curb emissions because of its certainty of the quantitative target and its political feasibility. However, emissions trading schemes always bear the risk of price volatility which poses a problem for firms’ decision making on investments in emission abatement. Hence price stabilisation measures are an issue in scientific literature as well as in political debate.

The report is structured as follows. In Section 2 the relevance of uncertainty and stable price signals in emissions trading schemes is discussed. Section 3 analyses price developments in the EU ETS in the period 2005 to 2010, and identifies the major drivers behind the observed volatility in the market. In Section 4 a summary of instruments that could be applied in carbon markets to manage and stabilise prices is provided. The functioning as well as alternative designs of these instruments are described and a (qualitative) evaluation according to various criteria is developed. Section 5 offers concluding remarks.

2 Emissions trading, uncertainty and price signals

Given the necessity to reduce carbon emissions in order to limit global temperature increase and to avoid the most detrimental effects of climate change, emissions trading was chosen as policy instrument by the European Union and was also proposed in the United States[2]. Its advantages were seen primarily in the certainty of the quantitative target, i.e. environmental effectiveness, and furthermore in its political feasibility[3] (Grüll – Taschini, 2011). However, achieving a certain emission limit comes at the cost of the risk of price volatility (Metcalf, 2009). Excessively volatile prices bear the risk of undermining the trading schemes' objectives and/or public support for it.

In contrast to other commodity or financial markets carbon markets are entirely motivated by the underlying regulation[4] (Wood – Jotzo, 2011). The environmental effectiveness of a trading scheme depends on achieving the targeted emission reductions. This in turn depends on the one hand on the stringency of the cap and on the other hand on the scheme's ability to provide stable regulatory conditions and incentives for firms. One way to reduce emissions is to induce abatement through emission saving investments[5]. Highly volatile CO_2 prices do not give clear investment signals and render firm's decision making and planning difficult. In addition to helping in identifying cost-efficient abatement measures, stable prices may also

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[2] In the USA emissions trading has been successfully applied for the control of air pollutants like SO_2 and NO_x (see e.g. Burtraw et al., 2005, Hanemann, 2010). In January 2009 the Regional Greenhouse Gas Initiative (RGGI) was started with the participation of ten North Eastern States. Furthermore, several initiatives for the introduction of a nationwide cap-and-trade scheme in the US were started and proposed in Congress (Metcalf, 2009).

[3] In the 1990s several attempts were made by the European Commission to reach an agreement on a common EU-wide energy and carbon taxation approach. However, no unanimous decision could be reached and eventually in 2003 the Energy Taxation Directive, restricted to the definition of minimum tax rates for energy sources, was adopted. For a summary of the political process see e.g. Hasselknippe – Christiansen (2003) or Speck (2008).

[4] "Behind the global interest in marketable permits for air pollution is the recognition that any meaningful climate change policy has to put a price on carbon dioxide emissions." (Grüll – Taschini, 2011).

[5] Other ways include shifting to less carbon intensive or renewable fuels, reducing or relocating production. While investment in low carbon technologies represents a long-term decision, fuel switching is regarded as the most important short-term abatement option (Rickels et al., 2010).

lead to a higher level of research and development for low carbon technologies as they indicate the value of emission reductions (Haites, 2006).

Too high prices can lead to excessive costs of compliance for regulated firms and can erode public support for the cap-and-trade scheme. The concern about prohibitively high prices is especially of importance before or shortly after the implementation of a trading scheme when actual abatement costs have not yet been revealed and political bargaining regarding targets and efforts is ongoing or actors still strive to understand the market (Murray et al., 2009, Metcalf, 2009, Burtraw et al., 2010). However, price spikes in active carbon markets can occur due to high fossil energy prices[6], unpredicted high economic growth or regulatory changes (e.g. decisions to limit the possible use of CDM credits or other offsets for compliance).

Too low emission prices eliminate the investment signal for low carbon technologies and can undermine the scheme's credibility. Low carbon technologies are in many cases characterised by higher costs than "conventional" alternatives. Thus, a certain return on investment is required to motivate these investment decisions[7], especially if a rather short time horizon is required for the pay back of an investment. If the long-term benefits from reducing carbon – represented by savings on emission allowances – are clouded, private investments might not be made. Thus wildly fluctuating carbon prices in the short term[8] will have the potential to undermine long-term (financial) incentives to mitigate carbon emissions (Mason, 2009; Tatsutani and Pizer, 2008).

Therefore, stabilising emission prices can be regarded as a prerequisite for ensuring environmental effectiveness, cost efficiency and for providing investment and innovation incentives for low carbon technologies.

The EU Emission Trading Scheme (EU ETS) started in 2005 and represents the largest emissions trading scheme worldwide, covering about half of the EU's CO_2 emissions[9]. The effects of

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[6] Energy prices represent a major influence on the prices for emission allowances. In principle, high energy prices would provide an incentive for energy savings. However, it is the relative prices, i.e. the differential between coal and natural gas prices that is of importance for the emission market (Rickels et al., 2020, www.pointcarbon.com). When natural gas prices are high (usually when oil prices rise as they are closely linked) firms that can switch fuels decide to use cheaper coal instead of gas. This in turn increases the (expected) demand for emission allowances and subsequently their price. This decision is especially relevant for power and heat generation that represents a large part of the EU ETS. For the effects of carbon prices on the dispatch order see Cowart (2011).

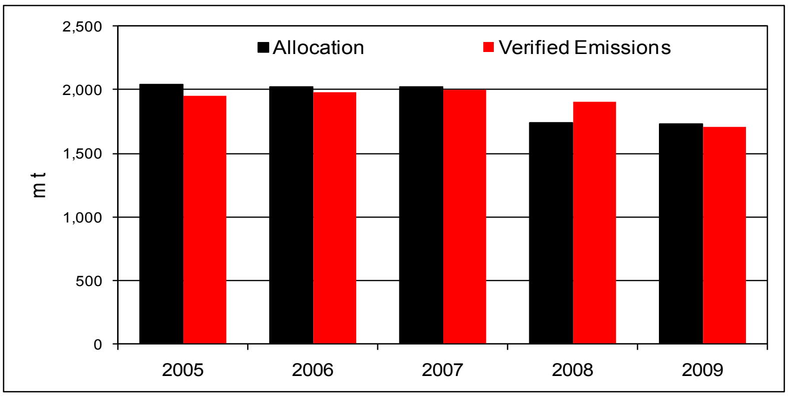
[7] Especially when taking into account that many relevant technologies have a comparatively long life time (e.g. energy generation equipment) and investment decisions therefore have long-term emission impacts (HM Treasury - HM Revenue and Customs, 2010).

[8] Short term price volatility merely reflects temporary phenomena like weather conditions, economic fluctuations, fuel prices etc. and should be reduced (Metcalf, 2009, Burtraw et al., 2010). Long-term price volatility cannot be avoided as technological as well as economic developments are difficult to predict and they have a large influence on abatement costs. In addition, new scientific results on climate change may require regulatory changes that also affect carbon prices (Tatsutani - Pizer, 2009).

[9] For a more detailed description of the scheme see e.g. (Kettner et al., 2010).

uncertainty became apparent for the EU ETS in the pilot phase in 2006 and in the effects of the economic recession in 2009. The first event refers to the sharp drop in allowance prices in spring 2006 following the publication of verified emissions indicating an oversupply of emission allowances. As the pilot phase was characterised by a non-binding cap due to generous allocations of allowances by the Member States, the EU Commission took stronger influence in the National Allocation Plans for the second trading phase, which resulted in a stricter overall cap in Phase 2 of the EU ETS (2008 – 2012). In 2008 the quantity of emission allowances thus was smaller than the verified emissions. With the external shock to the emissions trading scheme of the economic downturn in 2009 production declined sharply and also CO_2 emissions from manufacturing and energy generation thus attenuating the stringency of the emission cap for Phase 2. In contrast to 2008 in 2009 allowances again exceeded verified emissions (see Figure 3), creating the opportunity to bank allowances for later use in this compliance period or even for phase three of the EU ETS (2013 – 2020).

Figure 3: Allocation and emissions in the EU ETS, 2005 - 2009



Source: CITL; authors' own calculations.[10]

Whether or not regulated firms will have an incentive to abate emissions in Phase 2 will depend on the economic growth path until the end of 2012 and its effect on allowance prices. Thus, the – at the time of determining the Phase 2 emission cap – unpredictable economic crisis has led to a significant reduction in the stringency of the regulation and the incentive to invest in abatement technology[11].

[10] In order to ensure the comparability of data over time, data for Romania and Bulgaria as well as for Norway and Liechtenstein not included as installations from these countries are included in the EU ETS only since 2007 and 2008 respectively.

[11] For details on the effects of the economic crisis on sectors in the EU ETS see Kettner et al. (2011).

3 Price volatility in the EU Emission Trading Scheme

Since 2005 emission allowances (EUAs) have been allocated to installations in the EU ETS through grandfathering, i.e. for free based on historic emissions[12], and are freely tradable. Banking was allowed within Phase 1 of the EU ETS, but there was no possibility to transfer 2005 – 2007 allowances to the Kyoto period (2008 – 2012). For Phase 2 and beyond unlimited banking is allowed. A borrowing provision is included as one year's allowances can be used to cover the previous year's emissions.

In addition to the spot market for allowances also derivatives of different maturity (options and futures) on EUAs are traded. These can be regarded as instruments for market participants for hedging CO_2 related risks (Uhrig-Homburg – Wagner, 2009). Except for 2007 (see Figure 4) spot and futures prices develop in parallel and thus jointly contribute to price discovery (Cooper, 2010, Uhrig–Homburg – Wagner, 2009).

The analysis of prices in the EU ETS between 2005 and 2010 reveals that allowance prices have been far more volatile than previously expected[13] (see Figure 4). Allowance prices in the first phase – especially until March 2006 - did not conform to pre-market expectations, which generally predicted a low price level (Hintermann, 2010).

Essential drivers for prices and price fluctuations include fundamentals as[14]:

- The stringency of the cap;
- Economic fluctuations;
- Fuel prices;
- Fuel switching possibilities;
- Weather conditions;
- Market conditions and speculation;
- Regulatory decisions.

A range of these fundamentals had an influence on prices in the EU ETS as is shown in the following description of price developments[15] from 2005 to 2010.

The price started at around 7 € at the beginning of 2005, then rose to above 30 € in April 2006. This unexpected rise can be attributed to uncertainties, incomplete information prevailing in the market mainly regarding the stringency of the cap. High natural gas prices contributed to this trend by incentivising to use coal instead of gas. When in spring 2006 verified emissions for the first year were published and it became apparent that allocation of allowances had

[12] Except for small amounts that are auctioned.

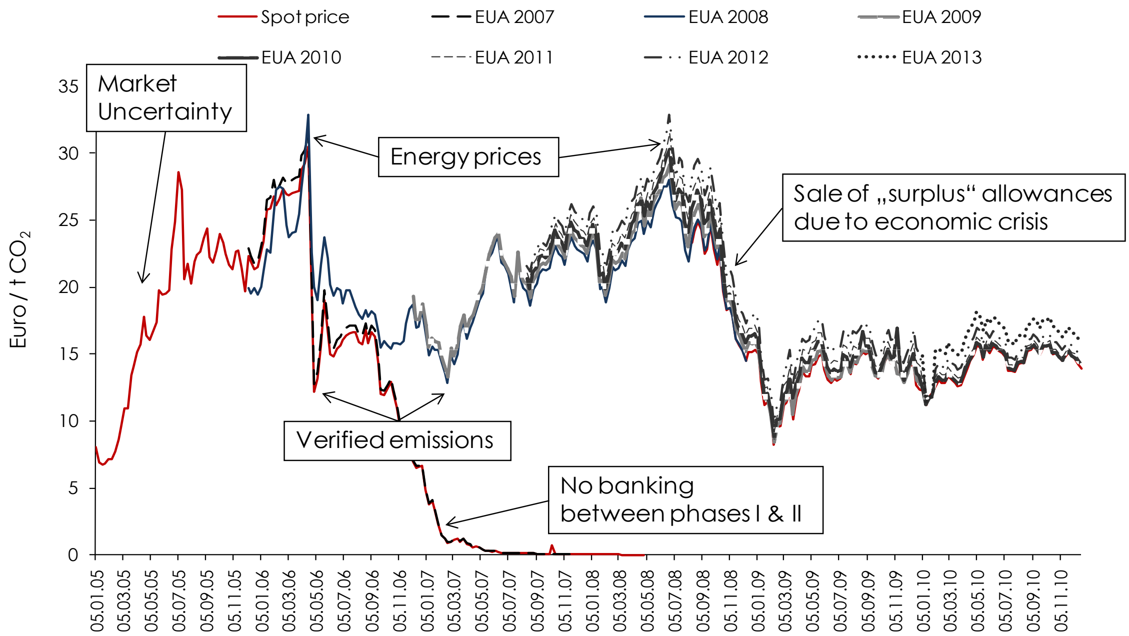
[13] As described by Metcalf (2009) and Stavins (2007) the price volatility observed in the EU ETS is no unique incident; similar price fluctuations occurred in the US NO_x trading and California's Regional Clean Air Incentives Market.

[14] See also Uhrig-Homburg - Wagner (2006); Benz - Trueck (2009), Feng et al. (2011); Rickels et al. (2010).

[15] For quantitative analysis of price drivers and volatility in the EU ETS see Feng et al. (2011), Chevallier (2011), Hintermann (2010), Rickels et al. (2010).

been overly generous[16] the CO_2 price collapsed to below 10 € within three days. It recovered to around 15 € for several months due to the power sector's short position[17] (Kettner et al., 2010) before in 2007 spot prices dropped practically to zero, as the overall long position for the whole EU in the pilot phase became evident and no banking of allowances between Phase 1 and Phase 2 was permitted so that surplus allowances became literally worthless. Futures prices for Phase 2 however remained at a level of 15 – 20 €.

Figure 4: Development of OTC closing prices in the EU ETS (2005 – 2010)



Source: *Point Carbon. EU ETS OTC closing prices.*

The first half of 2008 was characterised by high economic activity and rising prices for oil[18] as well as for emission allowances. After the onset of the economic recession a large amount of allowances was sold – either because they were not required for compliance by the firms' they were allocated to due to decreasing production especially in manufacturing or because firms intended to improve their cash-flow. This sale of surplus allowances led to a drop in prices from more than 30 € in September 2008 to 8 € in February 2009. Afterwards prices recovered again and remained relatively stable (with spot prices between 11 € and 15 €) until the end of 2010.

[16] As Hintermann (2010) points out, the over-allocation was merely a result of incomplete information on the side of the regulators (basing allocation on industry forecasts) rather than being intentional.

[17] Short position is defined as verified emissions exceeding the amount of allowances allocated to a sector.

[18] With the peak of 147 $/barrel in July 2008.

The analysis of price developments in the EU ETS between 2005 and 2010 leads to the conclusion that in Phase 1 fluctuations were mainly caused by incomplete information at the beginning, adjustments after the emergence of verified emission data and endogenous i.e. regulatory mechanisms (no banking between Phase 1 and Phase 2)[19].

However, the developments in the second trading phase reveal the strong influence of diverse fundamentals exogenous to the CO_2 market on emission prices. This includes the effects of high fossil energy prices as well as the impacts of unpredictable shocks like the financial and economic crises. The sensitivity of carbon prices to various endogenous and exogenous influences and the requirement to provide relatively stable investment incentives for market participants in order to achieve the emission reductions envisaged would suggest the implementation of practices or instruments to stabilise prices in the carbon market.

4 Price management instruments

There is a fundamental trade-off between a cap-and-trade scheme's main advantage, the certainty of the emission limit, and the likelihood of price volatility. As described above, strongly fluctuating prices (short-run price volatility) are counterproductive to business decisions as they do not deliver a clear signal regarding compliance costs. Fluctuating prices thus bear the risk of reducing or eliminating the incentive for implementing emission abatement measures. Various instruments could be integrated in a cap-and-trade scheme in order to reduce price volatility. These approaches include provisions for banking and borrowing, the approval of offsets for compliance purposes and combinations of price and quantity mechanisms that are usually termed hybrid schemes. These approaches are described in the following paragraphs, including a discussion of their advantages and disadvantages as well as possible design options.

4.1 Banking and borrowing

Banking and borrowing are key features in most cap-and-trade schemes for greenhouse gas (GHG) emissions proposed or implemented so far (also in the Kyoto Protocol). Banking allows regulated entities or countries to carry over unused emission allowances from one compliance period to another, while borrowing enables to use allowances from future periods for current compliance. Since climate change is not especially sensitive to annual GHG emissions, but ultimately depends on the cumulative stock of GHGs in the atmosphere, environmental effectiveness is ensured under banking and borrowing, as long as the cumulative emission cap of the program is not adjusted upwards and remains binding.

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[19] Phase 1 developments show the problems connected with a new and immature market (Rickels et al., 2010). However, they highlight certain interrelations and mechanisms that are of importance for the functioning of a carbon market.

Allowance banking and borrowing have an influence on the economic efficiency of the scheme and on the behaviour of emitters (Haites, 2006). If e.g. banking is permitted, there is an incentive for firms to carry out early emission reductions as the surplus allowances have a market value[20]. Banking and borrowing help emitters to deal with changes in production, demand or fuel prices by offering inter-temporal flexibility. Theoretical economic models have been designed to show how cap-and-trade programs with the option for banking and borrowing would allow firms to smooth abatement/compliance costs over time. Newell et al. (2005) showed that such a mechanism could offset the disadvantages of a cap-and-trade scheme relative to emission taxes, and, in principle, could even deliver a better outcome than carbon taxes. In terms of reducing price volatility this means that borrowing increases liquidity in the market when demand for emission permits is high and prices are rising by accepting the use of future periods' emission permits. This provides a certain insurance against the upwards price risk. On the other hand, when there is little demand for allowances banking reduces the downside price risk as allowances can be saved for later use.

Murray et al. (2009) showed in a simple two period analysis that "... *a cap and trade system with banking, borrowing, and an expectation of eventual adjustment of the emissions target can achieve the best possible outcome given the information that is known in period 1 even though policy is set in period 0*" (Murray et al., 2009, p.94). By allowing for inter-temporal flexibility within a cap-and-trade framework, new information on benefits, costs or expected target adjustments can be transmitted to markets today. In contrast, a tax framework would not allow firms that correctly anticipate future tax increases to arbitrage against this outcome by banking allowances for future compliance periods.

Pros:

- In the long term, banking and borrowing allow firms to shift the timing of their abatement activities, giving them more flexibility in managing their reduction obligations more cost effectively.
- Provisions for inter-temporal flexibility can contribute to stabilise emission prices and can help increase the liquidity of allowance markets and trading activity.
- Borrowing can reduce the potential for short term price spikes (upside price risk). Banking reduces downward pressure on prices when demand is low (downside price risk).

Cons:

- Firms may not always act rationally or with adequate foresight. Therefore, incorrect anticipations might trigger excessive borrowing in early compliance periods. By

[20] In contrast, without banking compliance and market activity have to be managed precisely every year because excess allowances have no value after the year they are issued for. Thus, if emissions are lower than the cap the price for allowances would converge towards zero at the end of the compliance period just as in the pilot phase of the EU ETS. In contrast prices would rise sharply of emissions exceed the cap (Haites, 2006). Inter-temporal flexibility in trading would especially reduce price fluctuations at the end of compliance periods.

depressing short-term allowance prices through such hoarding behaviour, the incentives for firms to develop and employ low carbon technologies could be undermined. The excessive borrowing in combination with under-investment in low carbon technologies might ultimately lead to extraordinary high permit prices in later compliance periods, where increased reductions are needed to repay the emission allowance debt.

- Unrestricted banking might lead to an "oversupply" of allowances in later periods in the case that the cap decreases gradually and the use of banked allowances from previous compliance periods enables firms to maintain higher emissions and further postpone the implementation of abatement measures. Such a development might for instance occur in the third trading phase of the EU ETS due to the decline in emissions and allowance demand following the economic crisis. However, aggregate emissions permitted over the whole period are not exceeded, as banking requires early abatement to take place. In addition, in case of a "stock" pollutant like CO2 the temporal shift does not aggravate the environmental problem (Haites, 2006)21.

4.2 *Offsets*

A complementary compliance option within a quantity based climate policy instrument is the recognition of offset credits. Such offset credits could be awarded for additional, verifiable GHG emission reductions achieved in sectors not covered by the domestic cap-and-trade program (so called 'domestic offsets'), or for qualified projects in other countries. The primary real-world examples for such an offset policy are the flexible mechanisms under the Kyoto Protocol – the Joint Implementation (JI) and the Clean Development Mechanism (CDM). While primarily introduced as mechanisms for technology transfer to less developed countries within the framework of the Kyoto Protocol, JI and CDM credits can be used up to a certain extent for compliance in the EU ETS. Linking of different carbon markets is usually regarded as one instrument to increase liquidity and for levelling emission prices[22]. The acceptance of offset credits can contribute to limiting the upside price risk in cap-and-trade schemes, i.e. the risk of excessively high compliance costs for regulated firms if abatement costs (and thus emission prices) are higher than previously expected.

Operating emissions trading schemes have defined a limit for offsets to be used for compliance (in the US RGGI it is 3.3% of an installation's total obligation, in the first trading phase of the EU ETS 11% of the installations' allocation[23]). However, if given price thresholds are reached the limit could be expanded (in the US RGGI for instance an expansion to 5% and 10% is possible) in order to increase liquidity and reduce the upward pressure on prices

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[21] For "stock pollutants" the impacts depend on the cumulative emissions over long time periods. In the case of "flow" pollutants (e.g. SO_2) impacts are determined by current emissions and hot spots can be created by temporal and/or regional shifts in emissions.

[22] For more details regarding linking see Türk (2011.)

[23] CDM credits for afforestation/reforestation measures were generally excluded.

(Grüll – Taschini, 2011). Excessive price fluctuations, especially price spikes can thus be avoided or reduced by introducing more offsets into the system. However, such offset expansion comes at the cost of losing the certainty regarding the emission target. On the other hand, cost containment by offsets can also be connected with the risk of lowering emission prices too far and thus reducing domestic abatement incentives.

Pros:

- In theory, the inclusion of offsets can significantly reduce the expected program costs. The flexible mechanisms under the Kyoto Protocol should generate incentives for pollution control to take place in those countries that have the lowest abatement costs by allowing trade of allowances across Annex I regions and by making it possible to obtain project based ERUs or CERs in Annex I as well as non-Annex I regions.
- Offsets may also be deployed to address short-term, unexpected cost risks. By modifying constraints on the use of offsets (e.g. by relaxing the limit on the maximum amount of offsets that can be used for compliance, by simplifying project verification requirements, or expanding the portfolio of eligible projects), potential upward price pressures can be moderated.
- International GHG emissions reduction projects, e.g. under the CDM framework, provide a mechanism for funding technological transfer from industrialised countries to less developed countries.
- Both industry (as a means of reducing compliance costs) as well as many environmental groups support the use of offsets (as a means of creating incentives to utilise important GHG mitigation opportunities).

Cons:

- If offset projects are not subject to a thorough verification process, which assures that the reductions are real, additional, permanent and verifiable, the environmental integrity of the program might be jeopardized[24]. In general, the introduction of offsets in the scheme is connected with a certain degree of variability in terms of the emission outcome.
- Excessive use of low-cost, low-quality offsets in a cap-and-trade scheme would drive down the actual carbon permit prices, in turn reducing firms' incentives to invest in low carbon technologies needed to achieve reductions domestically.
- The recognition of offsets in a cap-and-trade scheme would introduce the offset market as another determinant of permit prices. Changes in policies (e.g. forestry) in other countries or an increased competition for these international offsets as a result of

[24] However, the setup as well as the administration of such a verification process poses considerable practical challenges. The CDM for example is, based on the inherent difficulty of establishing a BAU scenario, by far the most complicated flexible mechanism of the Kyoto Protocol – while the rules for the ETS approved at COP 7 only amounted to a 5 pages document, the CDM rules run to 28 pages (McKibbin - Wilcoxen, 2002).

more stringent environmental regulations in other countries could drive up the actual permit price in the program.

- A potential response to these concerns about offsets would simply be the introduction of some constraints on the use of this mechanism. Such constraints could take the form of limiting the number of offsets that will be admitted in a given compliance period, or of limiting the types of projects eligible for offsets (Tatsutani and Pizer, 2009).

4.3 Hybrid systems

As we have pointed out, a quantity based economic instrument (a cap-and-trade scheme) does not provide certainty about the resulting permit prices. Nevertheless, a certain stability of future allowance prices and thus the return on investment is essential for firms to undertake investments in low carbon technologies. Even with the introduction of provisions in cap-and-trade schemes such as the approval of offsets, banking and borrowing, cost concerns can at best be alleviated but not removed, since neither offers cost certainty. Therefore a key alternative, which was initially suggested by Roberts and Spence (1976), is to establish a hybrid policy, which is characterized by elements of both a cap and trade scheme and a carbon tax.

The following paragraphs describe options for combining quantity and price based approaches in order to reduce price volatility in a carbon trading scheme.

4.3.1 Price ceiling

A price ceiling, i.e. defining an upper limit for the price of emission allowances, is one option to prevent an excessive cost burden for regulated entities in the case that emissions abatement is more costly than expected (see Figure 5 (b)). This approach offers more compliance cost certainty and a protection against the upside price risk of a cap-and-trade scheme.

One way to implement a price ceiling is a "safety valve" provision (Metcalf, 2009, Murray et al., 2009, Pizer, 2002). If allowance prices reach a predefined threshold (maximum price), firms can buy allowances directly from the government, providing cost containment (Pizer – Tatsutani, 2008). However, an unlimited additional supply of allowances at the ceiling price eliminates quantitative certainty and thus environmental effectiveness regarding the emission limit. In order to preserve a certain degree of environmental integrity the amount of allowances that can be purchased at the safety valve price can be constrained as proposed by Murray et al. (2009) under the title of strategic allowance reserve[25]. A restriction

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[25] A similar provision has been included in the EU's emission trading Directive (2009/29/EC) in Article 29a to deal with excessive price fluctuations: In the case that the allowance price is more than three times the average price of allowances during the two preceding years for more than six months, and the price does not correspond to changing market fundamentals, Member States may either bring forward their auctions or auction up to 25 % of the remaining allowances in the new entrants reserve.

of the additional amount of allowances is of particular importance in schemes with unlimited banking. If future allowance prices are expected to increase (e.g. because the cap is scheduled to be tightened), a conventional safety valve would lead firms to buy as many allowances as possible at the current ceiling price for later use, which would counteract the attempt to tighten the emission limit at least by the extra supply of allowances. The crucial task for the regulator is the definition of the appropriate amount of additional allowances in the reserve, which will depend on the stringency of the emission cap, the ceiling price and the acceptable extent of price volatility (Murray et al., 2009, Stavins, 2008[26]).

Alternatively, if paying a penalty is an alternative to compliance and missing allowances do not have to be surrendered as soon as possible, the penalty will effectively constitute a price ceiling.

Pros:

- A price ceiling represents insurance for emitters against unexpected price spikes and too high compliance costs.
- A predefined maximum allowance price increases predictability and contributes to ensure public support for the quantity based instrument.
- The provision of additional (limited or unlimited) allowances does not create costs for the regulator. In contrast, the revenues for selling allowances from the reserve at the ceiling price could be used to finance abatement measures in sectors not included in the emissions trading scheme (Metcalf, 2009).

Cons:

- Cost containment by a safety valve or an allowance reserve reduces emission certainty at least to the extent of the constrained additional allowance supply. Especially in connection with unrestricted banking, a future tighter emission cap may be compromised.
- After the intervention, allowance prices do not reflect real expectations or abatement costs (Grüll – Taschini, 2010). The cap on prices also constrains the incentive for abatement activities.

4.3.2 Price floor

The mirror instrument to a price ceiling is the definition of a minimum price for allowances (price floor, see Figure 5 (a)). This provides more certainty for firms that invest in abatement technologies and is especially important when abatement costs turn out to be lower than expected before implementation of the scheme. As summarised in Burtraw et al. (2010) costs have been overestimated rather than underestimated in implemented cap-and-trade

[26] Stavins (2008) suggests setting the safety valve price at the highest, socially acceptable level, such that only drastic price spikes are mitigated. In addition, revenues from selling the reserve allowances should be earmarked for financing abatement measures in non-ETS sectors, thus preserving environmental integrity.

schemes[27], giving increased importance to price floors as too low costs and thus reduced incentives for abatement seem to be the greater concern than overshooting prices. A price floor is a mechanism that ensures emission reductions also in the case when costs or allowance prices are lower than expected without the requirement to adjust the emission target (Wood – Jotzo, 2011).

As with a price ceiling there are various mechanisms to introduce a minimum price in a cap-and-trade scheme (Wood – Jotzo, 2011, Grüll – Taschini, 2011):

1. The regulator guarantees to buy back allowances at the floor price or to subsidise sellers when the price drops below the threshold level. This approach would however create an unpredictable financial burden for the regulator as ex-ante the amount of allowances that will be bought back or subsidised is not known.
2. A reserve price is determined for the auctions of allowances[28]. In this case, however, the market price could still fall below the minimum price. To what extent the auction reserve price determines an effective floor price depends on the share of permits that is auctioned. If the major part of allowances is allocated via grandfathering the market price would likely drop below the reserve price. In addition, if offsets can be used for compliance, they might also lower the price level. A reserve price will therefore limit the downward price risk but will most likely not determine a strict price floor (Wood – Jotzo, 2011).
3. Emitters have to pay an extra fee for each ton of emissions in addition to having to surrender allowances[29]. The fee could be either fixed or variable. In the first case the floor price equals the fee, which has to be paid in addition to the market price for allowances. In the second case the fee is only levied if the market price falls below the predefined minimum level. The fee would then amount to the difference between market price and floor price. In terms of budgetary effects a fixed fee would result in a predictable revenue stream while with a variable fee revenues accrue only when allowance prices are too low and income is unpredictable.

Pros:

- A price floor represents insurance for firms investing in low carbon technologies and abatement measures, guaranteeing a minimum return on investment and increasing

[27] This may be due to overestimated baseline emissions as well as asymmetric information between polluters and regulator.

[28] This approach was proposed in the Waxman-Markey Bill and is used in the RGGI scheme.

[29] The UK government intends to introduce a price floor for installations from the power sector in the EU ETS from April 2013 on. The floor will start at around 16 £ (18.4 €) per ton of carbon dioxide (tCO_2) and follow a linear path to target 30 £/tCO_2 in 2020 (35 €; both in 2009 prices). The price floor is intended to encourage massive investment in low carbon electricity generation by stabilizing prices. The floor price will be implemented in the form of a levy raised on power companies within the framework of the climate change levy (CCL) and fuel duty. So far most fossil fuels used to generate electricity are exempt from the CCL. The proposal intends to remove these exemptions and to tax fossil fuels at rates that take account of the commodities' average carbon content (HM Treasury – HM Revenue & Customs, 2010, 2011).

planning security. It stimulates innovation and investment by reducing the firms' price risk. This is especially important when the price drops drastically due to unexpected exogenous shocks to the trading scheme (e.g. an over-supply of allowances due to an economic crisis).

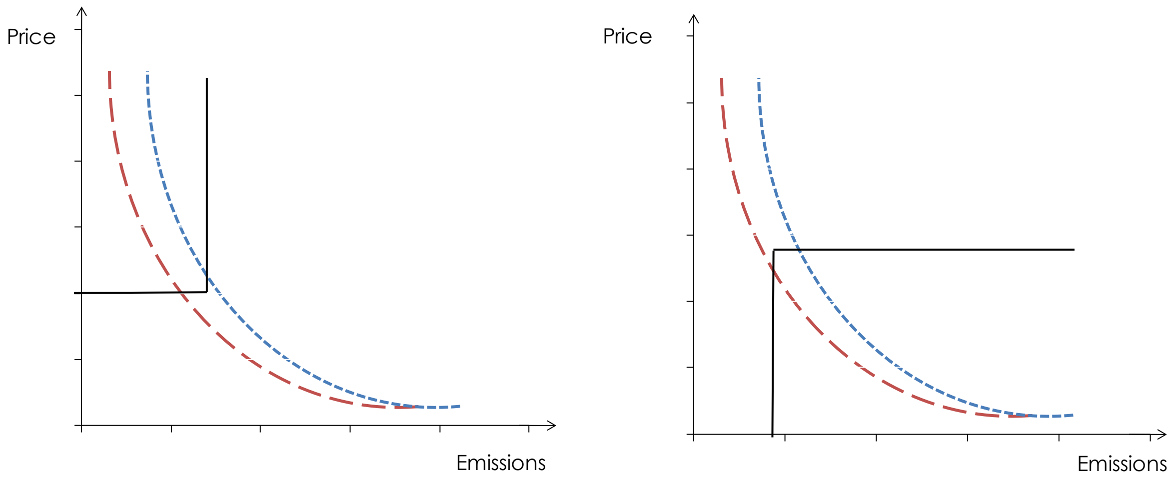
- The price floor could be implemented easily (as design element of the auctioning or as part of the existing tax system) and without compromising the advantages of a cap-and-trade scheme. In case of levying an additional fee the budgetary effects for the government are neutral to positive.

Cons:

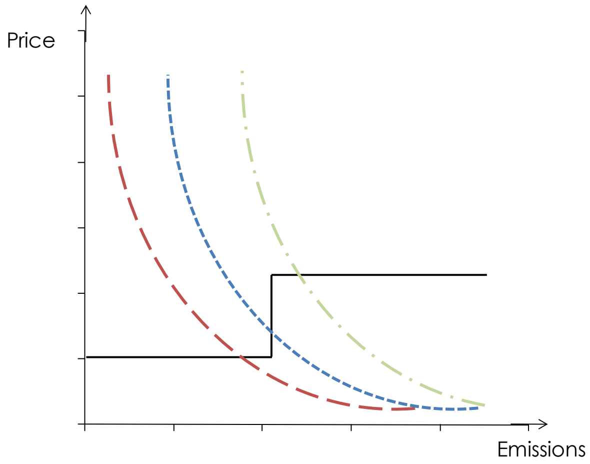
- Approaches for introducing a floor price may increase the complexity and transaction costs of a trading scheme.
- A price floor could lead to higher overall abatement costs. If the floor price is exercised, abatement could have been achieved at a lower price.
- In case of introducing a reserve price in allowance auctions the price floor might not be absolute, depending on the share of allowances in the system that is auctioned.
- In case of buying back allowances at the minimum price or subsidising firms that hold excess allowances if the market price drops below the threshold, the budgetary effects are unpredictable and might be substantial.

Figure 5: Hybrid systems

(a) Cap-and-trade with price floor *(b) Cap-and-trade with price ceiling*



(c) Cap-and-trade with price collar



Source: Own illustration, based on Wood – Jotzo (2011), Murray et al. (2009).
The curved dotted lines represent alternative marginal abatement cost curves (MAC' = cheaper abatement, MAC'' = more costly abatement); the solid line represents the carbon price for the policy options. The intersection of the curves gives the resulting emission level and price.
In a cap-and-trade scheme with a price floor (a) the guaranteed minimum price leads to lower emissions as compared to the outcome given the market price in case of the lower abatement costs. In a cap-and-trade scheme with a price ceiling (b) the upside price risk is removed but the resulting emissions are higher than in the case without a maximum price. The price collar (c) combines the mechanisms of price floor and ceiling.

4.3.3 A price collar for GHG cap-and-trade programs

A price collar or price corridor[30] for GHG cap-and-trade schemes is a combination of a floor and a ceiling price as described above. This aims at decreasing the permit price uncertainty on the high and low side and "*creates a more flexible response to the threat of climate change in the context of uncertain cost*" (Philibert, 2009). Under such a hybrid system, the allowance price would move within a predefined band between the fixed floor and ceiling. Over time the corridor could be adjusted, e.g. revised upwards as the emission cap becomes tighter (PriceWaterhouseCoopers, 2009, Figure 5). The setting of a price band combines the properties of quantity- and price-based approaches. The narrower the corridor, the more the scheme resembles a carbon tax, the wider it is the more it corresponds to pure trading. The main advantages of a hybrid scheme are limiting price volatility and compliance costs[31] on the one hand and ensuring abatement incentives and a certain reliability of the emission limit on the other hand. However, also the disadvantages of price floors and ceilings described above are of concern in a hybrid scheme. These include above all potential budgetary effects of a floor price and the loosening of the environmental target.

In addition, the market intervention may affect the regulated firms' trading strategies (Grüll – Taschini, 2011). When the market price is close to the price ceiling, firms short of allowances

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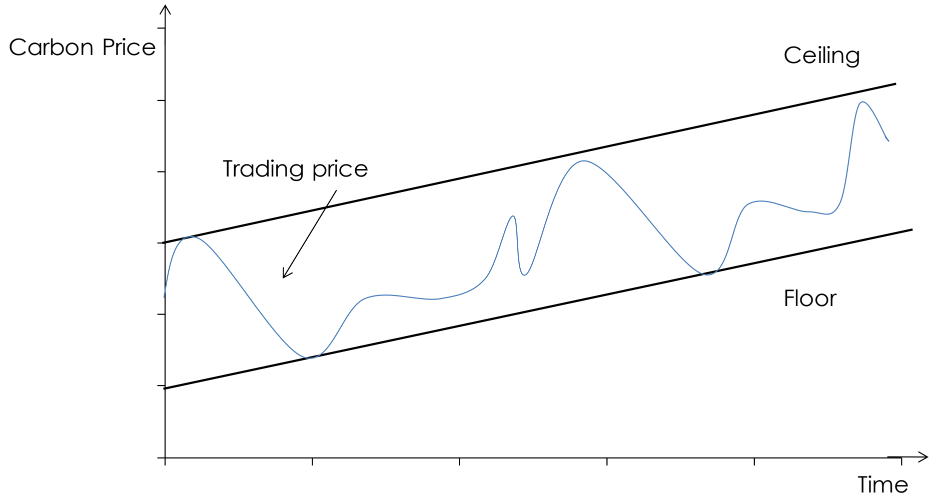
[30] Also named a symmetric safety valve by Burtraw et al. (2010).

[31] Modelling results indicating more efficient outcomes of hybrid systems compared to taxes or conventional emissions trading can be found in Pizer (2002),Burtraw et al. (2010), Fell – Morgenstern (2010), Philibert (2009).

will wait to see if prices fall before the end of the compliance period, as they would never have to pay more than the set maximum price. In contrast, firms that hold more allowances than they need to cover their emissions would be interested to sell at a high price as they cannot expect higher revenues. On the opposite side – i.e. with prices close to the floor – firms in permit excess would not be interested to sell, since they can expect revenues to rise, while firms in a short position would be willing to buy, thus minimising their expenditures for allowance purchases. These strategies prevent the permit price from moving outside the price collar.

Figure 5: Increasing price corridor in a cap-and-trade scheme



Source: PriceWaterhouseCoopers (2009)

5 Conclusions

Market based instruments for regulating greenhouse gas emissions are assumed to be more efficient than command-and-control regulation as they provide more flexibility for the regulated entities and allow for emissions reductions to take place where they are cheapest. However, quantity and price based instruments like emissions trading or carbon taxes deliver their optimal results only under the assumption of perfect markets and the absence of uncertainty. Under real world conditions, that imply uncertainties about numerous fundamentals like economic or technological developments, energy prices or regulatory changes affect the functioning of climate policy instruments.

One major advantage of emissions trading over taxes is the quantitative certainty, i.e. the determination of a limit on emissions that will be met. The environmental effectiveness is however related to uncertainty about the resulting carbon price and thus overall compliance costs. In this context one concern regards overshooting prices (if abatement is more costly than expected), that would lead to an excessive compliance cost burden. On the other hand falling prices do not ensure a minimum return on investment for emission reduction measures.

Prices in a carbon market have an important function as indication of abatement costs and the value of emission reductions, providing an incentive for low carbon investments. Strongly fluctuating prices distort or blur this investment signal, by reducing planning security and increasing investment risks. As experience from existing schemes (e.g. the EU ETS or SO_2 or NO_x trading in the USA) shows, price volatility is a central issue in emission markets. There is indication, however, that the downside price risk and thus the under-investment in abatement technologies plays a more important role than the upside price risk through drastic price increases.

In order to ensure the main objective of emissions trading schemes, achieving the environmental target cost efficiently and providing incentives for changes towards low carbon production structures, stabilising prices to a certain extent seems essential. Various mechanisms, like provisions for inter-temporal flexibility, linking to other emission markets or the combination of price and quantity regulation, can be used to increase liquidity in the market, reduce price fluctuations and provide more stable investment signals. Given the long-term nature of climate policy, the related uncertainties regarding technological change and political frameworks, and given a rising interest of institutional investors which might increase speculation in carbon markets, such price management approaches should be considered for the future design of emission trading schemes.

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