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Working Paper

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ZEW Discussion Papers, No. 08-081

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Zentrum für Europäische
Wirtschaftsforschung GmbH

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Zusammenfassung

Die Europäische Kommission hat in ihrem „Klima- und Energiepaket“ vom Januar 2008 eine Weichenstellung für den europäischen Emissionshandel vorgeschlagen. Bislang wurden die Zertifikate an die betroffenen Unternehmen aus den energieintensiven Sektoren kostenfrei vergeben. Nach den Plänen der Kommission sollen Stromproduzenten ab 2013 alle benötigten Zertifikate ersteigern müssen. Unternehmen aus anderen energieintensiven Branchen sollen zunächst nur 20 % ersteigern, in 2020 dann 100 %. Da insgesamt mindestens zwei Drittel aller Zertifikate versteigert werden, ist zu erwarten, dass der freie Markt für Zertifikate ab 2013 deutlich dünner sein wird als dies bisher der Fall ist. Aus diesem Grund gewinnt das Design der Auktion an Bedeutung, denn vom Auktionspreis, der die Knappheit an Zertifikaten signalisieren soll, werden wichtige Investitionsentscheidungen in CO_2-arme Technologien abhängen. Eventuelle Fehler im Auktionsdesign können, wenn die Zertifikate überwiegend versteigert werden, nicht mehr durch einen liquiden freien Markt „geheilt“ werden.

Das vorliegende Papier entwickelt Kriterien, nach denen unterschiedliche Auktionsdesigns für die Versteigerung von Zertifikaten bewertet werden können. Von zentraler Bedeutung für die Bewertung einer Auktion sind (i) verlässliche Preissignale, die die Knappheit der Zertifikate richtig widerspiegeln, (ii) die Vergabe der Zertifikate an Bieter mit der höchsten Wertschätzung und (iii) Transparenz und Glaubwürdigkeit in der Durchführung.

Unsere Analyse zeigt, dass eine Auktion für Zertifikate die folgenden Eigenschaften aufweisen sollte, um die genannten Kriterien zu erfüllen: Erstens, die Auktion sollte in Form einer „doppelten Auktion“ durchgeführt werden, d.h., ein Unternehmen sollte sowohl Zertifikate anbieten als auch nachfragen können. Zweitens, die Auktion sollte als „dynamische Auktion“ mit aufsteigendem Preis durchgeführt werden. Diese Auktionsform hat den großen Vorteil, dass die Bieter aus der Information über die Überschussnachfrage bei einem bestimmten Preis ablesen können, wie knapp die Zertifikate tatsächlich sind. Alle erfolgreichen Nachfrager zahlen in der Auktion den gleichen Preis. Drittens, es sollten Auktionen für Zertifikate aus zwei unterschiedlichen Handelsphasen (Phase 2: 2008-2012 und Phase 3: 2013-2020) parallel durchgeführt werden um sicherzustellen, dass Zertifikate aus beiden Phasen erworben werden können. Viertens sollten die Auktionen regelmäßig und mit einer glaubwürdigen Ankündigung, wie viele Zertifikate wann versteigert werden, durchgeführt werden.

Die einseitige Version dieser Auktion, bei der Unternehmen nur kaufen können, ist unter den zu erwartenden Marktbedingungen nicht geeignet, verlässliche Preissignale zu generieren. Zugleich sind die etwa in Deutschland durchgeführten direkten Verkäufe am freien Zertifikatmarkt in Phase 3 keine Alternative zu einer Auktion. Bei einem großen Angebot durch direkte Verkäufe auf einem dünnen Zertifikatmarkt ist eine Preisbeeinflussung höchst wahrscheinlich, was eine erhöhte Preisunsicherheit für die Marktteilnehmer zur Folge hat.

Non-technical Summary

Our paper is motivated by the "Climate action and renewable energy package" proposed by the European Commission in the beginning of 2008. It suggests auctioning as basic principle for allocation for the upcoming third trading phase of the EU Emissions Trading Scheme (Phase 3) that runs from 2013 to 2020. Explicitly, in the power sector 100 % auctioning is proposed from 2013 onwards. In all other sectors it is suggested to start with an initial auctioning share of 20 % in 2013, to be increased to 100 % by 2020. Overall, it is estimated that at least two third of the total quantity of allowances will be auctioned in 2013. The drastic increase of auctioned allowances in contrast to grandfathering in the past will change the market structure in Phase 3. For a given cap, with an augmenting auction supply the possibility to purchase allowances in the secondary market decreases. As a consequence, market liquidity is extracted suggesting a thinner secondary market than in earlier trading phases.

Based on the theoretical and empirical literature we firstly emphasize the importance of a properly chosen auction design as the significantly higher auction share, compared to the past and current trading phases, is expected to yield a thin, non-competitive secondary market for CO_2 allowances. Secondly, we elaborate main criteria that a viable auction design is supposed to fulfil and propose a specific auctions design for Phase 3. As criteria we state that the auction should create early and reliable price signals to support correct abatement decisions. The auction should also allocate the allowances to the firms that need them most, i.e. to the firms with the highest marginal abatement costs. Additionally, it should be designed simple and transparent to enhance trust and credibility of the market in the trading scheme and thus enforce intensive participation. Thirdly, we recommend a specific auction design. We argue that the regulator should apply a simultaneous dynamic uniform double auction, in order to achieve best the above mentioned criteria. In this auction firms may both buy and sell allowances. The dynamic implementation ensures that bidders get information over the scarcity of the allowances from the excess demand. Furthermore, all successful bidders pay the same price per allowance. In addition, we conclude that auctioning allowances of future trading phases is necessary to reduce future price uncertainty. Most effectively, this can be realized by an auction that offers allowances of the current and successive trading phase simultaneously.

We conclude that the most common auction design – the one-sided uniform auction – does not comply with all proposed criteria as it is not able to guarantee reliable prices. Besides, we discourage from direct sales, as they are currently executed in Germany, as alternative to standard auctions. With an increasing auction volume direct sales which are rather in-transparent may cause price effects in a thin secondary market and thus may increase price uncertainty in the trading scheme.

Auctioning of CO_2 Emission Allowances in Phase 3 of the EU Emissions Trading Scheme

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October 2008

Abstract

The "Climate action and renewable energy package" proposed by the European Commission in the beginning of 2008 suggests auctioning as basic principle for allocation for the upcoming third trading phase of the EU Emissions Trading Scheme that runs from 2013 to 2020. Overall, it is estimated that at least two third of the total quantity of allowances will be auctioned in 2013, to be increased to 100 % by 2020. In this paper, we emphasize the importance of a properly chosen auction design as the significantly higher auction share, compared to the past and current trading phase, is expected to yield a thin secondary market for CO_2 allowances. We elaborate main criteria that a viable auction design is supposed to fulfil and propose a specific auction design for the third trading phase. The auction we recommend is a simultaneous dynamic uniform double auction.

Key words: climate policy; emissions trading, auction design

JEL classifications: D44; Q48; Q54; Q58

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* The authors thank Michael Peichl for his research assistance.

1. Introduction

The EU Emissions Trading Scheme (EU ETS) represents one corner stone of Europe's strategy to mitigate emissions of greenhouse gases. Implementing a political viable allocation rule for the scheme constitutes a major challenge for the regulator, as some misspecifications might yield severe economic damages for the system, as experiences from the first trading phase (or Phase 1: 2005-2007) have shown. Currently, the European Commission (EC) – the regulator for the EU ETS – is concerned with the implementation of the allocation rule for the third trading phase of the EU ETS, also known as Phase 3, running from 2013 to 2020. In contrast to the allocation plans of Phase 1 and Phase 2 (2008-2012), a considerable fraction of allowances is intended to be auctioned such that the importance of a well designed auction institution increases drastically. According to the Directive of the EC (EC 2008) at least two thirds of the total available allowance volume (ET budget) will be auctioned in 2013, to be increased to 100 % by 2020.

The objectives of this paper are to elaborate main criteria by which relevant allocation mechanisms based on auctioning for Phase 3 can be evaluated and to propose a specific auction design that complies with these criteria: As with a significantly higher auction share it is plausible to expect a relatively thin secondary market for emission allowances, we argue that the allocation rule should foster the creation of early and reliable price signals. They help to reduce price uncertainty for future trading years and phases. Furthermore, an auction should allocate the allowances to firms that need them most, i.e. to firms with the highest marginal abatement costs. Both criteria support correct abatement decisions – the key element of emissions trading schemes (ETS). Additionally, an auction mechanism should be designed simple and transparent to make firms' participation as easy as possible and to be secure from abuse and resistant to market manipulation. Thereby confidence and credibility in the trading system are enhanced. Although additional criteria like revenue maximization, political feasibility, and social acceptance also have to be considered, they are secondary from the firms' point of view and thus do not constitute the focus of our analysis. Additional to auctioning, we include the possibility of free allocation in proportion to historical emissions or output (grandfathering) as part of the allocation process. With respect to auctioning we distinguish between standard auctions and auctions executed as direct sales into the market. We obtain our results by studying already existing auctions for ETS in combination with standard auction theory.

Our analysis reveals that, independent of the existence of grandfathering, the simultaneous dynamic uniform double auction (in which firms may act as buyers and sellers) is able to fulfil all criteria for the allocation rule. This auction is also known as simultaneous ascending clock auction allowing for a selling position. Not able to conform to the criteria is the one-sided counterpart (buying position only) in combination with free allocation, whose static version is applied already for selling allowances in Phase 2 of the EU ETS and is considered for other future trading schemes. In addition, we conclude that direct sales only constitute an attractive alternative to standard auctioning as long as the auctioned volume is relatively small.

The remainder of the paper is organized as follows. In Section 2 we present the past regulatory frameworks with respect to allowance allocation for Phase 1 and Phase 2 together with the improvements planned by the EC for Phase 3. The criteria to a viable allocation mechanism that is based on auctioning are defined in Section 3. In Section 4 we introduce the pool of multi-unit auctions for (almost) identical objects and then evaluate already existing auction designs for emission allowances in terms of their compliance with the criteria. Based on these results and with regard to the future EU ETS market structure, in Section 5 we formulate recommendations for a viable auction design for Phase 3 together with first suggestions for its implementation. The paper ends with a brief conclusion in Section 6.

2. Initial allocation rules in the EU ETS

The EU ETS, established in 2005, is made up of consecutive trading phases. Currently we are in the second trading phase that runs from 2008 to 2012 (Phase 2). Initial allocation rules for Phase 1 and 2 are governed by the “EU ETS Directive” (EC 2003). The Directive specifies that at the end of every February a certain amount of allowances, i.e. the initial allocation, is allocated to the installations subject to emissions trading for the current trading year according to so-called “National Allocation Plans” (NAP). More precisely, they regulate the ET budget and the allocation rule for each trading phase. Thereby, typically two basic types of allocation rules are employed: auctioning and grandfathering. According to the Directive, grandfathering is the rule but EU Member States were permitted to auction off up to 5 % of the ET budget in Phase 1 and up to 10 % in Phase 2. Four Member States allowed for auctioning in Phase 1, eight in Phase 2; in any case, the shares to be auctioned were well below the allowed maximum shares.[1] In other words, until 2012 the EC has chosen a hybrid initial allocation scheme where some allowances are to be auctioned and the dominating part is to be grandfathered.

For each upcoming trading phase it is the objective of the EC to refine and improve the EU ETS in the light of experiences gathered from the past. The current “Climate action and renewable energy package” proposed by the EC (EC 2008) suggests auctioning as the basic principle for allocation for Phase 3, i.e. there is a paradigm shift with respect to initial allocation. Explicitly, in the power sector 100 % auctioning is proposed from 2013 onwards. In all other sectors it is suggested to start with an initial auctioning share of 20 % in 2013, to be increased linearly to 100 % by 2020. However, the proposal introduces free allocation instead of auctioning as one measure to avoid potential competitiveness disadvantages of European industries from carbon regulation and so-called “carbon leakage”, i.e. the danger of loosing market share due to international competitors in non-regulated regions outside the EU and the associated relocation of CO_2 emissions.

Both methods of initial allocation, auctioning and grandfathering, are from a theoretical point of view neutral in their effect on marginal costs, but the use of grandfathering instead of auctioning has a positive effect on firms’ balance sheets. To what extent firms that are regulated by the EU ETS lose market shares depends on their market position and the carbon regulation prevailing for their competitors. Meanwhile, there are first studies that empirically tackle the question about the ability to pass-through carbon costs and its effects on firms’ market shares. The empirical results strengthen the use of full auctioning at least in the electricity sector. The IEA (2005) provides estimations for price elasticities of demand, and Zachmann and von Hirschhausen (2008) show that there is even asymmetric carbon cost pass-through in the case of German wholesale electricity prices. Löschel and Oberndorfer (2008) complement this finding by providing pass-through estimates for additional energy-intensive sectors. Their results suggest that there are important differences in pass-through behaviour at the sectoral and even sub-sectoral level. The calculations indicate, however, that strong ability to pass-through carbon costs as previously shown for the electricity industry might not be the rule. Given the difficulty to assess whether and to what extent sectors are likely to pass on the cost of carbon without loosing market shares,

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[1] The Member States employing auctions in Phase 1 are Denmark (5% of total allowances are auctioned), Hungary (2.5%), Ireland (0.75%), and Lithuania (1.5%). For Phase 2 the following countries have indicated their willingness to auction: Austria (1.3%), Belgium (0.3%), Germany (8.8%), Hungary (5%), Ireland (0.5%), Lithuania (2.8%), Netherlands (4%), Poland (1%), and UK (7%), see Schleich et al. (2008).

complementary indicators like the CO_2 cost impacts and the trade intensity of carbon intensive products are proposed to identify sectors at risk of "carbon leakage" (Hourcade et al. 2008, Oeko Institut 2008). Table 1 shows the EU ETS sectors, their energy intensity and trade intensity in 2005, and actual emissions and projections until 2020. Besides the EU auctioning proposal (Scenario I), two other scenarios are analysed where free allocation to address "carbon leakage" is based either on energy intensity above 3 % (Scenario II) or on trade intensity above 25 % (Scenario III). These scenarios reflect the recent discussion on competitiveness effects of climate policies in energy-intensive industries. In Germany, for example, the ministry of economics proposed to allocate permits free of charge to all energy-intensive manufacturing industries, i.e. business entities where the purchases of energy products and electricity amount to at least 3 % of the production value (Council of the European Union 2003), while the ministry of the environment proposed to give free allowances to industries with a trade intensity above a threshold which has to be specified yet (Mrusek 2008). The estimations show that the scenarios do not have a significant impact on the auction volume: in all three scenarios the fraction of auctioned allowances is roughly more than two third already in 2013 and rises thereafter. In other words, auctioning will be indeed the basic principle for allocating allowances from 2013 onwards even when competitiveness concerns of energy-intensive industries are taken into account.

Obviously, the drastic increase of auctioned allowances in contrast to free allocation in the past will change the market structure in Phase 3. For a given cap, with an augmenting auction supply the possibility to purchase allowances in the secondary market decreases.[2] As a consequence, market liquidity is extracted suggesting a thinner secondary market than in earlier trading phases. In this context, we refer to a *liquid* market if firms can buy or sell allowances without causing a significant movement in the market price, i.e. firms act as price takers.[3] As soon as this assumption has to be given up, the market is *imperfect* or *illiquid*. As illustration, one might think of a scale between zero and one, whereas the borders mark the two extreme cases of no and full auctioning. Moving from the left to the right border, the auction supply increases while, correspondingly, the liquidity of the secondary market decreases. Note that while in the secondary market firms' *net positions*, i.e. excess supply or demand given the initial allocation, are traded, firms are able to cover in the auction their *total*

[2] In a scheme based on grandfathering, liquidity in the secondary market is only created if firms are over or under supplied by the regulator. In a scheme based on auctioning, obviously there will be fewer deviations between firms' allowance demand and the allocation because firms will adapt their bidding behaviour to their actual needs.

[3] This is one of the standard definitions of market liquidity for financial assets, see e.g. O'Hara (1998).

demand of allowances. Therefore, a certain amount of allowances which is allocated either via an auction or via grandfathering has a different effect on liquidity in the secondary market. This aspect underscores the importance of a correct auction design.

Table 1: Total auctioning share in phase 3 under different scenarios

						Scenario					
	Energy intensity (EI) in % [a]	Trade intensity (TI) in % [b]	Emissions (in $MtCO_2$)			I (EU proposal)		II (EI > 3 %)		III (TI > 25 %)	
						in %					
EU ETS sectors			2005	2013	2020	2013	2020	2013	2020	2013	2020
Pulp and paper	9.6	29.4	24	28	24	20	100	0	0	0	0
Basic chemicals	5.1	32.5	67	61	49	20	100	0	0	0	0
Glass and glass products	6.1	19.6	46	44	38	20	100	0	0	20	100
Cement, lime and plaster	12.4	5.5	110	98	86	20	100	0	0	20	100
Basic iron and steel	7.4	33.6	183	144	118	20	100	0	0	0	0
Aluminium	6.0	37.9	14	12	11	20	100	0	0	0	0
Refined petroleum prod.	0.2	5.0	101	96	84	20	100	20	100	20	100
Coke oven products	0.1	40.2	2	2	1	20	100	20	100	0	0
Electricity production			1510	1312	1172	100	100	100	100	100	100
Air transport [d]			151	169	161	20	100	0	0	0	0
Total			2208	1966	1744						
Total auctioning share in %						73	100	68	72	69	79

[a] Energy intensity = energy purchase / turnover in 2005. Own calculations based on Eurostat.
[b] Trade intensity = (value of exports to non-EU + value of imports from non-EU) / (turnover + value of imports from non-EU); e.g. Carbon Trust (2008). Own calculations based on Eurostat.
[c] Own calculations based on Primes (2007) and European Commission (2007).
[d] Aviation is energy and trade intensive, electricity production is only energy intensive, see e.g. Stern (2006).

Why do we observe such a strong tendency towards auctioning? The NAP of Phase 1, mainly applying grandfathering, involved negotiations over allowances with a total value of about €27 billion per year.[4] Given the proposal by the EC (EC 2008), between 2008 and 2012 the average volume of yearly allocated allowances will be 1.89 $GtCO_2$. The total value of allowances will then be €47 billion per year (assuming an average price of €25/tCO_2). Political decisions on how to allocate the allowance budget between sectors and individual installations, thus, naturally created intensive lobby activity by all participants to get the

[4] According to the CITL data, the amount of allowances allocated to account holders was 2.096 (2.072, 2.145) $GtCO_2$ in 2005 (2006, 2007). Multiplying these quantities with the quantity-based market price (2005: 22.3€/tCO_2, 2006: 15.1€/tCO_2, 2007: 1.3€/tCO_2) results in the total market value for Phase 1.

maximum possible share of rents. Consequently, a lot of energy and time was devoted by firms, governments, and consultancy to the enormous rent allocation process, obviously, contradicting one of the main objectives of the EU ETS – cost-efficiency. Furthermore, sophisticated allocation rules, which are highly influenced by lobby groups, are not in line with simplicity and transparency, two further objectives of the EC's carbon regulation. An additional objective of emissions trading is to give reliable price signals. However, in Phase 1 the EU ETS was unable to generate such price signals: With the publication of the 2005 verified emissions data in April 2006, surplus allowances flooded the market and prices crashed by 60 % within one week as it became clear that participants had been granted around 10 % more allowances than they actual needed to cover their 2005 emissions.

To circumvent such price fluctuations and to ensure cost-efficiency as well as transparency and simplicity of the system, the preferred long-term option of the EC is full auctioning with free allocation only taking place during a transitional period based on harmonised EU-wide rules. Hereby, it is plausible to assume that transaction costs of an auction are less than the rent-seeking cost due to negotiating free allocation. Besides, no complex rules are needed to reward early actions to reduce emissions and to account for expected growth as well as for new installations and closures (Harrison 2002) or for the split between different sectors (Sijm 2002). Auctioning also avoids windfall profits and generates an outcome that may be perceived as "fair" because – in contrast to a free allocation – the "polluter pays" principle holds.[5] More explicitly, there are additional aspects that support the decision to implement an auction-based allocation rule. Firstly, grandfathering as it is implemented currently (for instance in Germany) creates perverse incentives as the amount of allocated allowances depends on the firms' fuel choice (e.g. Neuhoff et al. 2006). Power firms operating with coal get more allowances than firms using gas. This rule which is valid also for market newcomers prevents the switch from high- to low-carbon fossil fuel and increases the overall compliance costs of emissions abatement regulation. Last but not least, from the regulator's perspective, switching from grandfathering to auctions has no effects on prices for energy intensive goods and services but raises public revenue and, therefore, offers the potential to reduce distortionary taxes. Competitiveness concerns of industries under auctioning might be addressed by other measures to avoid or at least reduce carbon leakage, e.g. the increased use of the CDM mechanism, the inclusion of importers into ETS or the introduction of border-tax adjustment (BTA) (Alexeeva-Talebi et al. 2008). BTA consists of

[5] For the discussion of further arguments pro auction which concern distributional aspects see Hepburn et al. (2006).

tariffs on imported goods mimicking an (CO_2) tax on domestic goods and rebates for the domestic tax on exported goods. In order to make BTA compatible with principles of the Word Trade Organization (WTO), tariffs must be set at the average costs of CO_2 allowances excluding opportunity costs (Hepburn et al. 2006). Average costs, however, are only significant with auctions, and therefore, the introduction of auctions is a prerequisite to implement BTA.

3. Carbon auctions in emissions trading schemes

3.1 Example

How the allocation rule can influence the trading scheme or more precisely, how important a well designed auction is, especially in case of a thin secondary market, we illustrate my means of an example. We consider 5 firms that are committed to participate in emissions trading. Each firm has business-as-usual emissions (bau_i) of 200 tCO_2 such that in total 1,000 tCO_2 have to be covered by CO_2 allowances, with i being the firm-specific index. Each firm has one abatement measure, which can be activated to reduce its emissions volume up to a maximum quantity of 200 tCO_2 (potential abatement volume) at a certain price per abated tCO_2. The price is given by the firm's constant marginal abatement costs (MAC_i). The firms differ with respect to their MAC, such that there are low-, middle-, and high-cost abatement technologies (see Table 2), a quite realistic assumption in the EU ETS due to heterogeneous CO_2 abatement technologies. When grandfathering is part of the allocation rule firms possess an initial stock of allowances, labeled by s_i. If only auctioning is applied, then firms' initial allowance stock is empty. We assume that first the allowance allocation, i.e. the auction, takes place. Then, based on the auction outcome, that is the quantity purchased in the auction of firm i, q_i, and the auction price p_A, firms decide on their abatement volume a_i. Note that we do not consider a secondary market after the auction as we assume that it will be illiquid in Phase 3 of the EU ETS anyway. Hence, by studying the auction only in combination with abatement decisions we can demonstrate best the importance of a suitable auction design when there is no secondary market that is able to absorb auction inefficiencies that are mispricing or misallocation of allowances. Let us consider the case, in which the regulator decides on an ET budget of 900 allowances (tCO_2)[6] and considers three rules to allocate them that all include auctioning.[7]

1. Each firm is grandfathered 160 allowances (i.e. $s_i = 160$) and the remaining 100 allowances are auctioned. In the auction firms are only allowed to purchase allowances (one-sided auction).
2. Each firm is grandfathered 160 allowances (i.e. $s_i = 160$) and the remaining 100 allowances are auctioned. In the auction firms are allowed to purchase *and* to offer allowances (double auction).
3. The whole ET budget of 900 allowances is auctioned (i.e. $s_i = 0$). In the auction firms are only allowed to purchase allowances (one-sided auction).[8] Note that this scenario reflects the situations when there is no grandfathering, when banking from the previous trading phase is forbidden or when the ETS enters its first trading phase. In all situations firms do not have an initial stock of allowances.

In the example, 100 tCO_2 (the difference between total *bau* emissions of 1,000 tCO_2 and the ET budget of 900 tCO_2) have to be abated in total. Since the maximum abatement volume of each measure equals 200 tCO_2, the target is achieved cost-efficiently by the cheapest abatement measure (owned by firm 5). Thus, the lowest MAC determine the true market price, labeled by p^*, that reflects the market scarcity situation, i.e. $p^* = 10$ € per allowance.

Being interested in the influence of the auction design, we now investigate the auction outcome of the three different allocation rules that are labeled according to their incorporated institutions: grandfathering (GF), one-sided auction (A), and double auction (DA). Therefore, we need to make additional assumptions about the pricing rule in the auction and firms' bidding behaviour. First, the auction price is determined by the market clearing price, i.e. the price where demand equals supply. As explained in more detail in Section 4.1 this is a standard auction pricing rule. Second, in the auction each firm i demands its whole shortage (i.e. the difference $bau_i - s_i$) as long as the auction price $p_A < \text{MAC}_i$. If $p_A > \text{MAC}_i$ the firm stops bidding in the one-sided auction or switches to offering its whole stock of allowances in

[6] In the following the units "tCO_2" and "allowances" are used as synonyms.
[7] A detailed introduction into possible auction designs is given in Section 4.1 together with a motivation for the auction scenarios applied in the example.
[8] As the fourth combination (double auction with 100 % auctioning) generates the same results as the one-sided auction we refrain from presenting this scenario here.

the double auction, respectively. In other words, firms take their individual MAC as reservation price.[9] Consequently, the auction serves first the bid of the firm with the highest MAC, then the firm with the second highest MAC and so on until the whole auction supply is allocated. The auction price then lies between the lowest winning bid and the highest loosing bid. To keep the example simple, we adopt the rule that the market clearing price equals to the highest losing bid. Thus, the example yields the following auction outcomes with resulting abatement activities (see also Table 2):

Table 2: Example for allocation rules

Firm			GF+A			GF+DA			A		
i	bau_i	MAC_i [€]	s_i	q_i	a_i	s_i	q_i	a_i	s_i	q_i	a_i
1	200	50	160	40	0	160	40	0	0	200	0
2	200	40	160	40	0	160	40	0	0	200	0
3	200	30	160	20	20	160	40	0	0	200	0
4	200	20	160	0	40	160	40	0	0	200	0
5	200	10	160	0	40	160	-60	100	0	100	100
Auction price p_A [€]				30			10			10	

Explanation: Auction price p_A, initial stock of allowances s_i, purchased auction quantity q_i, and abatement volume after the auction a_i with the three allocation rules.

Allocation rule GF+A

Auction: Each firm demands $bau_i - s_i = 200 - 160 = 40$ tCO_2 at its MAC_i. The auction supply of 100 allowances is allocated to firms 1 and 2 which have the highest and second highest MAC. Each firm receives its bid and purchases $q_i = 40$ allowances. Firm 3 gets only the remaining $q_3 = 20$ allowances. As firm 3 does not receive is whole demanded quantity of 40 allowances, it has the highest loosing bid. Thus, its MAC determine the auction price $p_A = 30$ € per allowance, which is obviously higher than the market scarcity price $p^* = 10$ € per allowance. Firms 4 and 5 do not receive anything from the auction.

Abatement: After the auction firms 3, 4, and 5 still need allowances. If they consider $p_A = 30$ € as a correct market price signal for current market scarcity, they all have an incentive to abate their still missing quantities ($a_3 = 20$, $a_4 = 40$, $a_5 = 40$) at their individual

[9] This behavioural assumption is reasonable as it constitutes an equilibrium strategy in a perfect secondary market for allowances, i.e. if a single buyer's impact on the market price can be disregarded. Besides, this behaviour has been observed in ETS experiments, see e.g. Benz and Ehrhart (2007).

MAC of €30, €20, and €10 per allowance, respectively.[10] This behaviour obviously prevents cost-efficiency that is reached when firm 5 abates, only.

Allocation rule GF+DA

Auction: Each firm demands again 40 allowances at its MAC_i. The auction supply of 100 allowances is allocated as before to firms 1, 2, and 3. Additionally, as the auction allows for a selling position, firm 5 with the cheapest abatement technology offers its whole stock of allowances at its MAC of 10 € per allowance and thus sells 60 allowances; 20 allowances to firm 3 and 40 allowances to firm 4 ($q_3 = 20$, $q_4 = 40$). This leads to $p_A = p^* = 10$ € per allowance.

Abatement: Taking $p_A = 10$ € as market price signal, only firm 5 has an incentive to abate the whole reduction target of 100 tCO_2 ($a_5 = 100$). This constitutes also the cost-efficient strategy.

Allocation rule A

Auction: As firms do not have an initial stock of allowances, each firm demands 200 allowances at its MAC_i. The auction supply of 900 allowances is allocated to firms 1 through 4 ($q_i = 200$) and to firm 5 ($q_5 = 100$). Firm 5 has the highest loosing bid and determines the auction price $p_A = p^* = 10$ € per allowance.

Abatement: As before, taking $p_A = 10$ € as market price signal only firm 5 has an incentive to abate ($a_5 = 100$) and thus behaves cost-efficiently.

To summarize the examples' results, taking individual MAC as reservation price all allocation rules allocate the allowances to the firms with the highest willingness to pay (derived from their MAC). Note that if this criterion is guaranteed by the auction design, the auction allocation is called *efficient*; see e.g. Krishna (2002). However, how reliable the auction price p_A signals the market scarcity price p^* – obviously an important criterion for correct abatement decisions – crucially depends on the allocation rule: If firms possess allowances already before the auction, as it is the case for rules GF+A and GF+DA, this criterion is met only for the double auction (GF+DA). The signal of its one-sided counterpart (GF+A) is

[10] Note that at a market price of 30 € per allowance firm 3 is indifferent between buying allowances on the secondary market and abating emissions. For sake of simplicity, we assume that at the margin firms prefer to abate.

expected to exaggerate the market scarcity price and hereby prevents cost-efficiency. If firms do not possess allowances at the time of the auction this criterion is met for a one-sided auction as well as for a double auction.[11] Thus, we can state the following result:

Result 1 *The auction design does not matter with respect to allocation efficiency but it matters with respect to price signaling: Only the double auction is able to create reliable price signals of emission allowances, independent if grandfathering or banking is allowed or not.*

Obviously for 2013, the first year of Phase 3, the best price signal still might be the market price at the end of Phase 2 in 2012, i.e. the price signaling effect of auctions after the start of Phase 3 is rather insignificant. However, the example's result with respect to price signaling becomes important when high-volume auctions are conducted in future trading years of Phase 3 and future trading phases when we have to assume to have no perfect secondary market anymore that is able to signal reliable market prices before and after the auction.

3.2 Criteria

The following four main criteria are supposed to be fulfilled by a viable initial allocation rule for emission allowances, as also proposed by e.g. Benz and Ehrhart (2007), Cramton (2007) and the National Emissions Trading Task Force of Australia (NETT 2007).

(1) Price signaling

This criterion is associated with the generation of reliable price signals, which allow firms to profitably invest in cost-efficient abatement measures. A price signal is said to be reliable if it reflects the true scarcity of emission allowances in the system, which is necessary to identify the cheapest abatement measures – the most difficult but essential task in ETS. As most emissions-reducing investment projects, especially those with high energy efficiency, are costly and involve long implementation times, they require a long-term planning horizon. Therefore, the initial allocation mechanism should support the generation of reliable price signals at an early stage to lower uncertainty in the (future) secondary market and thus to foster cost-efficiency. As the shift from grandfathering to auctioning does not guarantee a

[11] As mentioned already earlier, the scenario of an exclusive double auction is not illustrated by the example as it yields the same results as allocation rule A.

liquid secondary market anymore whose market price can serve as reliable signal, the ability of an auction to generate such price signals is decisive.

(2) Allocation efficiency

This criterion stipulates that the firms with the highest willingness to pay should receive the allowances. In other words, allowances are to be allocated to those firms above all others needing allowances to comply with their commitment. Since the allocator is not aware of individual needs and grandfathering does not take them into account, Criterion 2 only applies to auctions. As it is reasonable to assume that in Phase 3 trading on the secondary market is dominated by the auction, this criterion is highly relevant. Auctions have to reach as much as possible from allocation efficiency as the secondary market might not be able to correct inefficiencies.[12]

(3) Simplicity, transparency, and credibility

This criterion is related to past experiences with the NAP, where immense transaction costs have been accumulated to negotiate free allocation that has fostered the discussion of using auctions by the EC (see Section 2). When switching to auctions it must be guaranteed that their design is kept simple and transparent to lower the cost of entry (training, consulting) and to attract a high number of bidders. Many auction participants make market power and collusion less likely. Besides, the auction process is supposed to be non-manipulative and should build up confidence among bidders and credibility in the trading scheme. Thus, an institution with high reputation where rules and offered quantities are contractually specified is necessary, especially when an increasing auction volume has to be handled in an environment of several competing selling institutions, as it may be the case in the EU ETS; possibly each Member State conducts its own national auction scheme or several auction platforms arise with different auction mechanisms.

Simplicity is not only desirable with respect to the allocation design but also to firm's successful participation in the ETS. Ending up with a successful outcome (in the auction and secondary market), i.e. receiving the demanded number of allowances without paying too much, should not be based on complex bidding strategies incorporating a lot of outside

[12] Note that Criteria 1 and 2, price signaling and allocation efficiency, imply Pareto efficiency where no mutually beneficial transactions are possible.

information (e.g. about other firms' characteristics or total scarcity conditions). Firms' simplest strategy one might think of is to bid straightforward, i.e. to tell their private valuation for one allowance, which is given by their marginal abatement costs. Thus, the allocation mechanism should guarantee that a simple strategy already yields a successful outcome as well as a more sophisticated one. Additionally, firms should have ex-post no incentive to change their bidding strategy.

(4) Revenue raising

Auctions have the advantage over grandfathering that they generate public revenue and offer the potential to reduce distortionary taxes. Thus, Criterion 4 also applies to auctions only. The capacity of an auction to raise reliable revenue streams is a relevant design criteria but it is not declared as primary objective of the auction design and should not be pursued at the expense of the other criteria. Revenues should be ideally recycled outside the scheme to prevent rent seeking on the revenue spending.[13]

3.3 Auctioning: timing, volume, and products

The timing of the auctions influences their ability to comply with Criteria 1-4. Generally, auctions benefit of a high reputation because of their ability to reveal information that helps to generate price signals (Criterion 1). Dependent on the auction design, the revealed information is reliable or not (see example in Section 3.1). However, in the environment of ETS the price signaling effect depends additionally on the timing of the auction. Obviously, the signaling effect is strongest if the auction is conducted well before the start of the ETS (*early auctions*) in order to plan and realize profitable abatement strategies with long lead times and long life times.[14] For already operating ETS, as the EU ETS, only so-called *spot auctions* (auctions of allowances valid for the current trading phase) and *advance auctions* (auctions of allowances valid for future trading phases) are of relevance.

Evidently, price signals from spot auctions have a rather short term effect on the secondary market. However, if they are conducted in regular time intervals they can guarantee

[13] According to the EC at least 20 % of the auction revenues generated in Phase 3 should be used for green purposes such as contributing to research and development for reducing greenhouse gas emissions, to adaption measures, to avoiding deforestation or to address social aspects such as possible increases in electricity prices in lower and middle income classes (EC 2008).

[14] A recent example is the auctioning of allowances for the US RGGI scheme. While the scheme will start in 2009, first allowances have been already auctioned in September 2008.

allowance supply for buyers and new entrants and lower market uncertainty. The latter aspect is particularly important in case of an illiquid and highly volatile secondary market as assumed for Phase 3 that is not able anymore to generate reliable price signals before and after the auction. Obviously, in case of a small auction supply or a perfectly operating (liquid) secondary market auctions might loose importance over time and are quickly dominated by the market (see the US SO_2 market for example, Schmalensee et al. 1998).

Advance auctions can also set (early) price signals for the future and ensure liquidity of allowances before the trading phase they can actually be used for. Hence, they might account for possible time delays at the start of a new trading phase and help to decide on investment projects having a long-term planning horizon, which spreads over several trading phases. Certainly, as there is no ban in banking between the trading phases of the EU ETS (EC 2008), the allowance purchased in the spot auction is the superior product: It can be used in either the current or any future trading phase, whereas the product of the advance auction can be used only in a later trading phase. Consequently, the allowance price in the spot auction must be at least as great as in the advance auction. Therefore, across trading phases we deal with inhomogeneous auctioned products whereas during a specific trading phase products are identical.[15]

In principal, advance auctions can be considered as equivalent to futures markets for standardized contracts on CO_2 allowances. However, in the context of Phase 3 the existence of a liquid futures market for Phase 3 allowances already before 2013 is rather implausible for the same reason why the secondary spot market might be illiquid; a high auction supply decreases the possibility to buy allowances on the market. Currently, only futures with expiry until 2012 are available. Thus, to reduce uncertainty for a power firm to be short in 2013 or later in Phase 3 a mix of spot and advance auctions for the ET budget is necessary.

Result 2 *Advance auctions (auctions of allowances for future trading phases), additional to spot auctions (auctions of allowances for the current trading phase), ensure liquidity in the future and thus reduce uncertainty in the EU ETS.*

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[15] If market actors expect allowance prices to increase faster than the rate of interest, then the price of the spot auction will approximately equal the price of the advance auction; otherwise, the price of the spot product will be above the price of the advance product, see Cramton (2007).

4. Auction designs

In the example of Section 3.1 we have briefly introduced two different types of auctions: the one-sided auction and the double auction. In the following, we first embed these two setups into possible auction designs and demonstrate their application in already existing trading schemes. We discuss their compliance with Criteria 1-4 and finally recommend an auction design for Phase 3. Note that illustrated by the example, we have to distinguish between two auction environments: an environment in which firms possess already emission allowances (via grandfathering or banking) and one in which they do not have allowances, yet. Obviously, for Phase 3 the first environment applies.

4.1 Introduction into multiple-unit auctions

In general before getting started, every regulator (or auctioneer) needs to specify the object that is to be auctioned. In case that he has several objects, he must decide whether to sell them separately in several auctions or in a single auction. As discussed in Section 3.3, emission allowances of one trading phase are sold in identical units of one tCO_2. However, allowances from different trading phases are close but not perfect substitutes. Possibly, they constitute to a certain extend complementary units in case that future investment decisions are taken for more than one trading phase. In any case, we deal with *multi-unit auctions for (almost) identical objects*. Furthermore, the auctioneer has to be aware of the information that is available to him and to the bidders. It is reasonable to assume that he does not know the precise valuation for one allowance of each bidder. That is the maximum amount each bidder is willing to pay, which is given by firms' individual marginal abatement costs. Otherwise there would be no need for an auction. Besides, bidders also may not know exactly the valuation of other bidders and even their private valuation might be difficult to assess (due to e.g. uncertainty about future fuel prices, product demand, and technology progress). Thus, the pure so-called private value situation does not apply for the allowance auction.[16] This is enforced by the fact that the allowances can be traded in the secondary market, whereby the value of the allowance becomes the same to all bidders, however, unknown at the time the auction takes place – a so-called "common value" situation.

Additionally, the auctioneer needs to specify the objectives that the auction should generate, which are in our case Criteria 1-4: price signaling, efficient allocation, and

[16] The assumption of private values is most plausible when the value of the object to a bidder is derived from its private consumption or use alone and do not consider the opportunity to resale it (i.e. paintings, jewellery).

simplicity combined with transparency and credibility as main objectives, but also revenue raising. It is the auctioneer's task to implement a set of rules that guarantees best these objectives. In general, he has the following possibilities for implementation:

- *Static* (also *single-round or sealed-bid*) or *dynamic* auction. A static auction only consists of one round of bidding, in which bidders simultaneously and independently submit their bids. A purchase bid consists of two components, the quantity and the price, that the participant is willing to pay per unit. Contrary, in a dynamic auction bidding is an iterative process. In general, the auctioneer raises (decreases) the auction price in each round and bidders permanently must submit a quantity bid to signal their willingness to stay in the auction. This procedure is repeated until total demand is below (above) or equal to total supply. The units are then allocated at the prior price, and are rationed, if necessary, for those that reduced (increased) their quantity in the last round. The activity rule is simply that each buyer cannot increase (decrease) its quantity as the price rises (falls). This auction is also called *ascending (descending) clock auction*, in which a clock symbolizes the current round and indicates the corresponding auction price. The clock continues until the market clears (see e.g. Cramton 1998). The motivation for using a dynamic auction rather than a sealed bid auctions is that it allows for better price discovery. Bidders can learn from the bidding process and condition their bids on this information as explained in detail in Cramton (1998) and Ausubel and Cramton (2002).
- *One-sided* or *double* (also *two-sided*) auction. In a one-sided auction, the auctioneer, i.e. in our case the government, serves as the exclusive seller whereas in a double auction there are several sellers allowed; additional to the government firms can offer their allowances in the auction. Double auctions are also called two-sided auctions.
- *Uniform* or *discriminatory* (also *pay-as-your-bid*) price rule. A price rule specifies the price that a winner has to pay for the unit(s) in the auction. In a uniform price auction all bidders pay the same auction price per unit, which is the market clearing price when bidders' demand meets the auction supply. In a pay-as-your-bid auction, the winners pay the price they have stated in their bids. This means that bidders may pay different prices. There is theoretical and empirical evidence that the uniform pricing rule is to be preferred in the context of multi-unit auctions. According to Friedman (1991) the uniform price format leads to more truthful bidding because the fear of the winner's curse is reduced. Besides, it is strategically simpler as it reduces bid preparation

costs and thus encourages more bidders to participate. Reinhart (1992) and Chari and Weber (1992) also argue that uniform price auctions reduce market manipulation.

- *Reserve price*. By setting a reserve price the auctioneer defines the minimum price for the sold unit(s) to prevent a decline in prices below a certain threshold. Riley and Samuelson (1981) discuss the optimal reserve price in detail.
- *Sequential* or *simultaneous* auction. This distinction is only relevant when different types of units are sold. In a sequential auction each type is sold in separate auctions conducted one after another while in a simultaneous auction all types of units are sold in one auction. According to Porter et al. (2006) and Cramton (2007) a simultaneous auction can guarantee best the generation of efficient auction prices when different types of units are sold.

4.2 International experience with auctions for emissions trading schemes

The one-sided auction mechanism constitutes the most common and easiest format for auctioning identical objects. For instance, in Phase 1 of the EU ETS Hungary, Ireland, and Lithuania conducted static one-sided auctions; whereas dynamic sequential one-sided auctions have already been applied by the US market for NO_x as well as by the UK ETS for CO_2 allowances. However, in all these markets the sole reason for auctioning was to raise revenue to finance administrative costs. Besides, the insignificant budget-share of auctioning in Hungary (2.5 %), Ireland (0.75 %), and Lithuania (1.5 %) weakens the auctions' importance. Consequently, we abstain from a detailed analysis of all these auction designs as with respect to auctioning in Phase 3 the auction volume will be significantly higher and other objectives come to the fore by the EC, see Criterion 1-4.[17]

However, the US Acid Rain Program for SO_2 permits – the most prominent ETS before the EU ETS – conducts static double auctions with the objective to generate price signals and an efficient allocation (Cason 1993, Schmalensee et al. 1998). Consequently, a closer look at SO_2 auctions might be a good source of inspiration for developing an appropriate EU carbon auction design, even if the annual auction supply of 2.8 % is rather small. Explicitly, SO_2 permits are sold via annual static discriminatory auctions with a "low-

[17] For a detailed description of those auction designs we refer to Fazekas (2008).

offer-to-high-bid" matching rule.[18] However, it turned out that the discriminatory price rule induces sellers and buyers to misrepresent their true valuation of the emission permits and to state lower asking and bid prices.[19] The results of the first conducted auctions were low trading activity and an auction price that was smaller than the expected price in the secondary market that contradicts Criterion 1. However, in the course of the time both prices converged. To prevent such situations, in which the auction design invites bidders to take strategic considerations, the design needs to comply with Criterion 3. That is, successful participation should not base on complicated strategic bidding behaviour. The auction rules should give incentive to tell the true valuation for one emission allowance (given by individual MAC), which constitutes the easiest bidding strategy. This criteria is in line with the idea of Cason and Plott (1996) who conducted an experiment for testing the SO_2 auction with uniform pricing reflecting thus the allocation rule GF+DA studied in our example in Section 3.1. In their study they obtain a higher allocation efficiency level (Criterion 2), a more truthful revelation of underlying values and costs, and thus more accurate price information (Criterion 1).

With the gained knowledge from the example in Section 3.1 and the US SO_2 auction we preliminarily conclude that a uniform double auction seems so be an appropriate candidate for Phase 3, especially when grandfathering is still part of the allocation rule. Academic support comes from the experiment conducted by Benz and Ehrhart (2007) who test several allocation rules for emission allowances. They conclude that with uniform double auctions the regulator is always on the safe side, as independent on firms' bidding behaviour, bidding individual MAC or a more sophisticated strategy, all criteria are fulfilled.

4.3 US and Australian emissions trading schemes

The two most recent developments in the area of ETS come from the US and Australia. In the US, the Regional Greenhouse Gas Initiative (RGGI) – a cooperative effort by 10 North-eastern and Mid-Atlantic states to reduce CO_2 emissions in the electricity sector by means of emissions trading starting in 2009 – has agreed to auction at least 25 % of their emission allowance budget. The first auction was held already in September 2008. However, contrary

[18] Bids are ranked from highest to lowest. Based on this ranking the governmental auction supply is allocated first. The received firms' offers are then matched with the remaining bids, such that the lowest minimum offer serves the highest remaining bid.

[19] The lower the stated asking price of a seller, the less likely it is that any other seller has a lower bid, which increases the probability of winning. As with a discriminative price rule the buyer has to pay his bid price, he also has an incentive to under reveal his valuation. Thus, there is a downward bias on the auction price.

to academic advice by Cramton (2007) to conduct dynamic uniform double auctions, the program recently has decided to use a static one-sided auction format to allocate the allowances (RGGI 2008).[20]

After the ratification of the Kyoto Protocol, Australia plans to implement a national ETS by the end of 2010. In a first proposal, the regulatory authority, the National Emissions Trading Taskforce (NETT), suggests implementing an allocation rule using both, grandfathering and auctioning, and votes for the dynamic uniform double auction (NETT 2007).

4.4 Danish and German "direct sales"

Obviously, a wide variety of selling institutions falls under the rubric of "an auction". So far, when using the term "auction" we referred to the standard institution as a one-time event held by third party intermediaries, the auctioneers. However, in Phase 1 instead of a standard auction the Danish government agreed on selling the budget-share of auctioning (5 %) directly in the secondary market via a professional broker. As the objective was to maximize revenue, selling took only place in high-price periods. This way of auctioning is also implemented by the German government for the years 2008 and 2009 of Phase 2 to annually auction 8.8 % of the total national allowance budget (Zuteilungsgesetz 2007). Here, the governmental auction supply is offered continuously via a professional financial institution in almost equal portions (dependent on current liquidity of the most liquid futures contract) on standard trading platforms of the secondary market (BMU 2008).

Note that the mechanism of a double auction, whose total auction supply is the sum of the supply issued by the government and the firms for each possible price, is principally equivalent to a continuous trading scheme, in which the governmental supply is offered on trading platforms for allowances in regular and publicly announced time intervals (direct sales). The main problem of this selling alternative, however, is that with a high auction supply the volume gets too large to handle by the exchanges without having an impact on the market price. This strategy is thus prone to induce market uncertainty, especially as there are no generally accepted standards and rules for the selling strategy (e.g. announcement of the selling date, offered and sold volume). Consequently, the continuation of rather in-transparent direct sales in Phase 3 will not serve as appropriate selling institution, mainly in regard to

[20] This auction design, a static one-sided auction, was tested experimentally, too. See Holt et al. (2007).

other Member States. Assuming that in 2007 Germany – responsible for about 20 % of the total ET budget[21] – allocates allowances exclusively via continuous direct sales, the responsible financial institution gains market power and might influence the market price. In contrast, credibility is enhanced best if the selling of allowances is organized by an external auction platform with high reputation where rules and quantities are contractually specified and made public in order to minimize the amount of discretion in the process. A consistent auction format guarantees best transparency and non-manipulation. This aspect is important especially in the long run perspective when the secondary market is assumed to be not perfect. Particularly, in artificial markets such as ETS regulatory uncertainty may be reduced by a credible commitment of the regulator to sell an ex-ante specified quantity of allowances by an external auction platform in the market. This line of reasoning is based on the well-known argument for "rules rather than discretion" by Kydland and Prescott (1977) in order to avoid time-inconsistency of public policy.

Result 3 *As in Phase 3 (2013-2020) about two third of the total emissions trading budget is going to be auctioned, conducting standard auctions is superior to direct sales.*

5. Auction recommendation for Phase 3 of the EU ETS

A profound decision for a specific auction design makes it necessary to analyse the environment, in which the auction for Phase 3 is going to be embedded. First, contrary to the US RGGI and Australian ETS, the EU ETS has been established already in 2005 and has developed the infrastructure for the spot and futures markets. Thus, from the pool of auction types introduced in Section 3.3 we only have to consider spot and advance auctions. Early auctions are not relevant anymore by definition. In addition, at this point the volume of banked allowances from Phase 2 to Phase 3 is difficult to assess due to the lack of verified emissions. It could serve as indicator for liquidity in the secondary market at the beginning of Phase 3. Evidently, in case of a small volume, a well designed auction would be more important as the secondary market will not be able to absorb auction inefficiencies. In order to be prepared for all possible market scenarios, optimally, an auction design is required that can deal with all associated uncertainties. In other words, the right auction design may serve as insurance against a possibly illiquid secondary market.

[21] Own calculations based on CITL data (accessed in August 2008).

Consequently, the environment of Phase 3 reflects the two situations of the example in Section 3.1 where firms possess a positive stock of allowances, i.e. allocation rules GF+DA and GF+A are relevant. Remember that if bidders take their individual MAC as reservation price both the one-sided auction and the double auction generate an efficient allocation of the allowances (Criterion 2). However, with respect to price signaling, Criterion 1, the *double auction* performs better than the one-sided auction. The economic explanation for this result is quite intuitive. If only the government sells allowances in the auction (i.e. one-sided), only those companies which have relatively high abatement costs have an incentive to participate in the auction (in the example: firms 1, 2, and 3); net sellers are not expected to participate in the auction (in the example: firm 5). Thus the companies that will participate in the auction represent a biased sample of all companies that are involved in the ETS. If bidders do not take this issue into account the auction becomes more competitive than the later secondary market leading its closing price to overestimate the future development of the market price. For this reason, it is appropriate to extend the auction and allow firms that already possess allowances to sell them in the auction at a more reliable price. This adds complexity but as a consequence of a less biased sample of participants the auction will generate more reliable price signals than its one-sided counterpart.

We chose the *uniform price rule* as it is simple and transparent. There is one auction price for all winners and, as motivated in Section 4.1, it gives stronger incentives to tell firms' true abatement costs (Criterion 3). Obviously, the best signaling effect is achieved if the auction is run *dynamically*, more precise with an ascending clock, such that it provides the bidders with information through the process of bidding (see Section 4.1). Last but not least, to account for the possibility to buy and sell allowances for future trading phases, we recommend implementing a *simultaneous* dynamic double auction, i.e. to run a spot and advance auction simultaneously. Hereby, it is important that the bidding rules are kept as simple as possible to attract the maximum number of potential bidders and guarantee efficient prices for both types of allowances. That is, the price of the superior spot auction product must be at least as high as the price of the inferior advance auction product. Running two independent auctions sequentially cannot control for the latter issue (see Cramton 2007). The simultaneous auction gives bidders the opportunity to shift demand between Phase t and Phase $t+1$ allowances through the auction in order to account for their potential substitutability. Of course, bidding rules need to be designed as such that they prevent from non-monotone bidding behaviour.[22]

To summarize, the auction we recommend is a *simultaneous dynamic uniform double auction* also known as *simultaneous two-sided ascending clock auction*. It is able to fulfil Criteria 1-4. There is theoretical as well as empirical evidence that this auction is well suited to allocate emission allowances. Ausubel and Cramton (2004) prove that in absence of market power final prices of the simultaneous ascending clock auction correspond to the competitive equilibrium and the allocation is therefore efficient. This result holds for units that constitute substitutes as well as complements.[23]

Result 4 *The simultaneous uniform double auction in its dynamic form is able to fulfil best the criteria to a viable allocation rule for Phase 3 of the EU ETS and at the same time to absorb possible regulatory uncertainties with respect to Phase 3.*

Realizing this auction, the following important aspects have to be considered by the auctioneer: How often should the auction take place? How is the allowance share offered in spot and advance auctions? How to combine the governmental and firms' auction supply? To guarantee a source to purchase allowances gradually through a trading phase, quarterly auctions might be appropriate, as also proposed by Cramton (2007) and Holt et al. (2007). Obviously, the allowance share of forward auctions depends on the cap announcement by the EC: The earlier cap decisions are taken before the beginning of the upcoming trading phase, the longer Phase t spot auctions and Phase $t+1$ forward auctions can be run simultaneously. In practice this means that beginning from 2010 onwards, a certain fraction of "Phase 3 allowances" could be auctioned already. Thus, countries which employ partial auctioning in Phase 2 can implement spot and forwards auctions already simultaneously. From 2013 onwards only Phase 3 allowances are auctioned until the EC has decided on the cap for the next trading phase (Phase 4), possibly from 2021 to 2028. After then, advance auctions for Phase 4 allowances are again implemented. Assuming, that future trading phases last for a

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[22] As emphasized in Section 2, raising of auction revenues (Criterion 4) is not a primary objective of the auction design. We are not aware of studies that show that the recommended auction generates lower revenues then its alternatives. We assume that there are no significant differences in revenues.

[23] In a recent experimental study, the one-sided counterpart of the simultaneous ascending clock auction has been proposed already by Porter et al. (2006) for the Virginia's NO_x allowance auction. Testing several auctions, the authors found that the ascending clock performed best, as measured by revenue maximisation and allocation efficiency. However, due to time constraints the auction could be implemented only sequentially in the field.

period of eight years and the cap is always set about four years in advance, a 50-50-split of the ET budget between the spot and forward auctions might be plausible.

Besides, we recommend aggregating the governmental and firms' auction supply curves. This yields a unique supply curve indicating the quantity that is sold at various prices, optimally starting at a reserve price. To make participation for sellers more comfortable, firms should be allowed to submit their individual (upward sloping) supply curves, a sequence of price-quantity pairs, before the auction starts. The publication of the aggregated supply curve would then reveal important information to the demand side that enforces the process of price signaling.

Generally, the regulator's costs of the auction depend on the complexity of the design and the auction frequency. Obviously, the implementation of a dynamic auction is more costly than its static counter part. However, as electronic markets for European emission allowance trading already exist they can be used as auction platforms. Thus, implementation costs should have no significant effect, even for a dynamic two-sided setup as both buying and selling positions are implemented already. For example, in 2006 the Hungarian electronic auction was implemented on *euets.com* and in 2007 on the *Climex* trading platform that also conducted Lithuania's auctions.[24] The additional transaction costs of an auction incurred to the bidding firm are assumed to be only high at the beginning (consulting, training, working time) but can be disregarded as soon as regular participation is part of the day-to-day business.

According to the EC, the auctions must be conducted in an open, non-discriminatory manner (EC 2008), i.e. there are no restrictions on participation such that all firms have full access in case of the existence of several auction platforms. Dependent on potential bidders, activity rules on bidding behaviour are necessary to restrict influence on the auction outcome. However, the risk of executing market power in the EU ETS, presumably coming from the electricity sector, is rather small. In 2007 the electricity firm with the largest share of allowances only accounted for 7.2 % of the ET budget allocated to the electricity sector. Additionally, calculating the Herfindahl-Hirschman Index – a standard measure for market concentration – for this sector in 2007 yields 0.0035 indicating that no electricity firm

[24] Detailed information to both auction designs can be downloaded on http://www.euets.com/content/Download, accessed in August 28, 2008.

possessed any real market power so their influence on the auction outcome will be insignificant.[25]

6. Conclusion

Our paper is motivated by the "Climate action and renewable energy package" proposed by the European Commission in the beginning of 2008. It suggests auctioning as basic principle for allocation for the upcoming third trading phase of the EU ETS (Phase 3) that runs from 2013 to 2020. Overall, it is estimated that at least two third of the total quantity of allowances will be auctioned in 2013, to be increased to 100 % by 2020. These fractions are quite robust given different assumptions with respect to the amount of grandfathering in the non-electricity sectors. We emphasize the importance of a properly chosen auction design as the significantly higher auction share, compared to the past and current trading phase, might yield a thin secondary market for CO_2 allowances. We then elaborate main criteria that a viable auction design is supposed to fulfil and propose a specific auctions design for Phase 3.

As criteria we state that the auction should create early and reliable price signals to support correct abatement decisions. The auction should also allocate the allowances to the firms that need them most, i.e. to the firms with the highest marginal abatement costs. Additionally, it should be designed simple and transparent to enhance trust and credibility of the market in the trading scheme and thus enforce intensive participation. Studying the general auction literature and evaluating already existing auctions for emission allowances, we receive a pool of potential auction candidates. We conclude that the most common auction design – the one-sided uniform auction – does not comply with all proposed criteria as it is not able to guarantee reliable price signals. Besides, we discourage from direct sales as alternative to standard auctions as with an increasing auction volume they might have an impact on the market price and therefore cause price uncertainty in the trading scheme. We argue that the regulator might be on the "safe side" by applying a uniform double auction, preferably in a dynamic manner. In addition, we conclude that auctioning allowances of future trading phases is necessary to reduce future price uncertainty. Most effectively, this can be realized by an auction that offers allowances of the current and successive trading phase simultaneously. To sum up, we propose a simultaneous dynamic uniform double auction.

[25] According to own calculations based on CITL data (accessed in August 2008).

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