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Auctioning Greenhouse Gas Emissions Permits in Australia

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Abstract

The allocation of permits is an important design aspect of an emissions trading scheme. Traditionally, governments have favoured a free allocation of greenhouse gas permits based on individual historical emissions (“grandfathering”) or industry benchmark data. As, particularly in the EU, the free allocation of permits has proven complex and inefficient and the distributional implications are politically difficult to justify, auctioning emissions permits has become more popular. The EU is now moving to auctioning more than 50% of all permits in 2013 and in the U.S. the Regional Greenhouse Gas Initiative (RGGI) has started with auctioning 100%. Another case in point is the Australian proposal for a Carbon Pollution Reduction Scheme (CPRS) which provides for auctioning a significant share of total permits. This paper discusses some important theoretical and practical aspects of designing an auction for allocating emissions permits in Australia. The specific design details proposed here have been adopted by the Australian Government in their CPRS White Paper. Particularly interesting is the proposed structure of auctioning multiple emissions units of different vintages simultaneously.

Keywords

Climate policy, Greenhouse gases, Auctions, Emissions trading

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1. Introduction

Political interest in auctioning emissions permits has grown. Free allocation is plagued by windfall gains of emitters, as seen in the EU experience (Sijm et al 2006), and the inevitable contentious debate about who should get the permits. Most notably, environmentalists have criticised that a free allocation of permits is a transfer from the public to the emitting companies and, typically, these transfers increase with the size of the company's past and/or expected emissions. From a social perspective, consumer protection agencies have argued that it is not fair that the consumers have to bear the (opportunity) costs of emissions permits which are part of the tariff calculation of the power companies even if the permits were allocated for free.[1]

Besides the political arguments related to distributional impacts, there are good economic reasons for auctioning emissions permits (Cramton and Kerr 2002). First of all, any administrative allocation procedure is likely to be – at least temporally before secondary market trading occurs – inefficient as it cannot guarantee that it allots the permits to those who value them most — those with highest abatement costs. Second, an auction – if appropriately designed – may serve as a mechanism to elicit the market value of an item. This aspect is particularly important in an emissions trading scheme. Many abatement measures require long-term planning and need years before becoming effective. Thus, early price signals generated by a well designed auction reflect the economy's marginal costs of greenhouse gas abatement and, thus, help the decision makers to identify those measures which should be implemented from an economic efficiency perspective and those which should not. Third, auctioning emissions permits generates public revenues which are less disruptive of economic efficiency than

[1] The German federal consumer association (Verbraucherzentrale Bundesverband) claimed, for example, that power generators abused the trading of emissions permits for windfall gains at the expense of the consumers (Deutsches Verbändeforum, 2005).

taxes on profits or income.[2] Moreover, these proceeds partly offset the afore-mentioned shift from the consumer to producer surplus and can be used to counter regressive impacts.[3]

This study draws on lessons from auction theory and experiments, as well as experience of the authors with practical applications of large-scale auctions. It is a follow-up to a report by the same authors to the Australian National Emissions Trading Taskforce (NETT).[4] The report discusses crucial aspects of auctions for the initial allocation of emissions permits and proposes a specific design which takes the requirements defined by the NETT and their emissions trading proposal into account.

The NETT was institutionalized by the Australian State and Territory Governments in 2004 in order to develop a multi-jurisdictional emissions trading scheme. Its establishment can be seen as a response to the Federal Government's refusal to implement a cap on CO_2 emissions. With the 2007 elections, the political attitude towards greenhouse gas emissions changed dramatically and in its White Paper (Commonwealth of Australia 2008) on a Carbon Pollution Reduction Scheme (CPRS) the new Federal Government to a large extend has adopted our recommendations for the auctions of the allocation of permits.

This paper summarizes the original auction proposal to the NETT and transfers it in the context of the CPRS laid out in the White Paper. The first section gives an overview of the CPRS design elements relevant for the auction. In section two we discuss relevant theoretical and experimental literature. In section three we explain the goals of the auction. Section four out-

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2 Using the auction revenue to reduce other distortional taxes such as income tax is similar to the "double dividend" discussion in relation to environmental tax revenues which would improve the overall efficiency of the economy (Goulder 1995)..

3 Betz and Neuhoff (2008) argue that low-income households bear a larger relative burden of a cap on emissions than high-income households as they spend a higher share of their income on emissions intensive goods such as electricity. The regressive effect may be reinforced as low income households do not benefit as much from higher share values due to free allocation of permits since shareholders are mainly high-income households. If permits are auctioned, the revenue can go to funds which (partly) compensate poor households for commodity price increases associated with climate policy.

4 The report has been published in parts as Evans and Peck (2007).

lines the details of the auction design recommended to the NETT and subsequently adopted by the CPRS White Paper.

2. Principal design aspects of the proposed Australian emissions trading scheme

The Australian Government's (Commonwealth of Australia 2008) White Paper outlines the proposed Carbon Pollution Reduction Scheme. The government foresees that the legislation will be passed by mid-2009. The main features of the CPRS and the related fact sheets published by the Australian Government can be summarized as follows:[5]

The CPRS is to cover around 70% of Australia's Greenhouse Gas Emissions which will include a wide range of emitting sources (e.g. electricity industry to transport sector), some of them will be covered downstream some upstream.[6]

The Scheme is to start on the 1st of July 2011.

In the first year (2011-12), permits can be acquired at a fixed price of 10 $/ t CO_2-equivalent and permits cannot be banked. There will be no cap on permits and permits cannot be transferred into future periods, i.e. banking will not be allowed (Australian Government, 2009). From 2012-13 on, permits – so called Australian Emissions Units, AEU) - are assumed to be date-stamped (vintages) and bankable (this means if an AEU is not being used for compliance in a given year, it can be transferred to, and used in, later years without restrictions); moreover, a small share of borrowing is foreseen (5% of fu-

5 In May 2009 some new measures and changes have been proposed to the White Paper proposed design for the CPRS, see http://www.climatechange.gov.au/whitepaper/measures/index.html

6 A *downstream* approach requires fossil fuel users to acquire emission allowances compared to an *upstream* approach which requires permits to be acquired by fuel producers

ture vintages can be used before they become valid). Full trading of permits will start in 2012-13.[7]

For the first four years of the trading scheme (2012-13 to 2015-16), a price cap will be introduced. This cap will be raised by 5% (to adjust for inflation) per year. The future shape of the permit price cap will be reviewed at the first independent review.

Some permits are to be allocated for free to so-called strongly affected industries (electricity generation) as well as Emissions-Intensive and Trade-Exposed Industries (EITE); these sectors are to receive free allocation based on output data multiplied by a benchmark.[8]

Auctioning will start with the vintage 2012-13 and the first advance auction of this vintage is scheduled to be held in 2010-11. We estimate that the auction share will be more than half of the AEUs of one vintage. The share may change over time with changes in the output of EITE sectors or in case the coverage is extended and agriculture is included.[9]

Permits have to be surrendered on the basis of annual monitoring and reporting.

One-sided international linkages will be made possible by the use of the Clean Development Mechanism (CDM) and Joint Implementation (JI); the export of AEUs, however, will not be allowed.

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[7] The diverse impacts of the price cap on efficiency, effectiveness and fairness are discussed in Jotzo and Betz (2009).

[8] Details on allocation rules for EITEI see White Paper and accompanying documents: www.climatechange.gov.au.

[9] There is no auction share published in the White Paper and data for EITE is not available on the disaggregated level to actually calculate the free allocation. Therefore we used the free allocation share of 25% given in the White Paper for the EITE and the published number of free permits to strongly affected industries (which was converted to around 6%). This results in an auction share of around 70%. However, the recently announced Global Recession Buffers which increase free allocation to EITE industries will reduce this amount further.

As in the EU, an Australian Emissions Unit (AEU) allows its owner to emit one tonne of CO_2 equivalent. Whereas a European Union Allowance (EUA) is valid for a given compliance period (e.g. Phase II for five-years, Phase III for eight years), Australia plans for a finer granularity. As indicated before each AEU will have a date stamp (vintage), which indicates the year for which it will become valid. Inter-temporal flexibility is given by unlimited banking and some limited share of borrowing.

Thus, emissions permits of different vintages are partial substitutes: A permit with an earlier vintage can always substitute for a permit of a later vintage, but the reverse is not true as long as the later vintage is from a future year and the share of borrowing (5%) has been exhausted. Once the current calendar year becomes the later vintage, they eventually will become perfect substitutes.[10]

With respect to production technologies and long term abatement measures, one year is a rather short time frame. In so far as investments into efficiency improvements are concerned, companies would like to have some indication of the value of a future permit possibly years in advance. A natural approach is to allocate that part of permits that is subject to long term emissions management approximately isochronous with the investment decisions. The allocation of permits which relate to short term fluctuations e.g. in energy consumption, however, can occur later. This means, on the one hand, that it makes sense not to allocate all permits of the same vintage at the same time. It follows, on the other hand, that at a particular point in time permits of different vintages might be allocated simultaneously. An appropriate auction design should take this aspect into consideration. If a bidder seeks to acquire permits of a particular vintage, but an earlier vintage were available for less, the auction should provide the bidders with the flexibility to choose the earlier vintage as it serves the same purpose. Moreover, the auction should generate a price structure which yields valuable information with respect to the expected development of the scarcity of permits in the future. Thus, we

[10] Two permits of the same vintage are of course always perfect substitutes.

will need an auction format that is suited to simultaneously sell many units (AEUs) of different products (vintages) to bidders who have multi-unit and multi-item demand.

3. Related literature

The early literature on tradable permit systems like Dales (1968) typically assumed that permits are sold to the polluters. Some years later, Montgomery (1972) showed that the outcome (equilibrium price) is not impacted whether permits are auctioned or freely allocated. His finding combined with the political difficulties to achieve acceptance for auctioning may explain why in actual environmental markets auctions have rarely been used. Established schemes that did apply auctions, such as the Acid Rain programme or the NOx trading system in the US, auctioned only a small share of the total allowances or the auction design was flawed (e.g. Cason and Plott, 1996; see also Evans and Peck, 2007).

Within the EU Emissions Trading System (ETS) the auction share was limited up to 5% in Phase I (2005-2007) (CEC 2003). Only four EU members (Denmark, Hungary, Ireland and Lithuania) decided to auction off parts of their ET budget – a total of only 4.4 Mt of CO_2–e per year, or 0.2% of the entire ET budget in the first phase (Betz, Schleich, Rogge 2006). In Phase II (2008-2012) the auction share was limited by the Directive (CEC 2003) to up to 10%. Only 6 of 27 Member States of the European Union have chosen to auction allowances in this Phase. An analysis of the auction experience in the EU is given in Evans and Peck (2007). In Phase III, the adopted Directive (CEC 2009) foresees a much higher share of auctioning. Auctioning will be the dominant allocation method for the electricity sector and will become more relevant for other sectors as free allocation is gradually phased out by 2027 – apart from free allocations to sectors with a risk of leakage.[11] However, as the EU ETS is based on phases and not on vintages, and already has a liquid spot market, the auction design may differ from that of the CPRS. E.g. the current design in the UK for Phase II is a uniform-

[11] Emissions leakage can occur where there may be an increase in GHG emissions in a country without climate policies *as a result of* any decreases in production associated with the domestic climate policies of another.

price sealed bid auction. The Regional Greenhouse Gas Initiative (RGGI) in the US is also using uniform-price sealed bid auctions. Again the units have a different character to those of the CPRS, since they have 3 to 4 year compliance periods and a maximum of 2 auctions on any auction date can be conducted (RGGI 2008).

There is a rich literature on multi-item and multi-unit auctions, both theoretic and experimental. The theoretical analysis of auctions is rather easy if we restrict it to bidders with a demand of only one item (or one unit). In this case many of the results known from single-item auctions still hold. Engelbrecht-Wiggans and Kahn (1998), for example, illustrate the fundamental changes if one allows for bidders who have a demand of up to two units. A more general analysis of multi-unit demand of homogeneous items is provided by Ausubel and Cramton (2002). The general theme of this literature stream is that with multi-unit demand bidders may bid rather defensively compared to their valuations or what is known from single-unit auctions. As a result, the outcome of multi-unit auctions may well be inefficient.

A further generalization is to consider auctions of multiple heterogeneous items. A rigorous analysis is given in Armstrong (2000). The assumptions of the underlying economic situation, however, are rather simple as Armstrong considers items with independent valuations. More realistic are situations in which the valuations of the items put up for auction are characterized by interdependencies, either complements (a bundle of items is worth more than total value of the individual items) or substitutes (a bundle is worth less than the sum of its individual values). Bidding now becomes more complex and additional difficulties such as the exposure problem may arise. The literature focuses on bundle bids and efficiency and often benchmarks possible auction formats with the Vickrey-Clarke-Groves (VCG) mechanism, an extension of the Vickrey auction (Vickrey, 1961). For combinatorial reasons, however, bidding in a VCG auction is difficult and is infeasible if the number of items is large. For an overview of combinatorial auctions see Cramton *et al.* (2006).

Most of the above papers investigate auctions in which the bidders have private valuations of the objects, i.e. they know exactly how much a particular item or a bundle of items is worth to them. This assumption may not hold in the context of greenhouse gas permits as bidders face uncertainties about the development of abatement technologies, future demand for their products or the future prices of alternative fuels.[12] Focusing on multi-unit demand with uncertain valuations, the theory is much less developed (see, e.g. Ausubel, 1999). The issue becomes even worse if we are looking for an analysis which deals with different items (vintages in the emissions permits context) and many units (AEUs). Similarly, the experimental literature does not deal specifically with auctions that bring together all of the important features related to the AEU auction. This is especially true with respect to the multi-unit and multi-item aspects. Manelli, Sefton and Wilner (2006) experimentally compare the static Vickrey auction with a dynamic variant (Ausubel 2006). The experiment is interesting in so far as it involves common-value components. However, each bidder has identical values for up to only two units and values a third unit at zero. Heterogeneous items are not considered.

Porter *et al.* (2009) is among the only experimental work which addresses the interaction between multi-unit and multi-item aspects of different auction types.[13] They experimentally compare clock auctions and a sealed bid auction in both a simultaneous and sequential setting where multiple units of two different items are being offered. Moreover, the context is very similar to the AEU auction as Porter *et al.* investigate potential designs for the Virginia NO_x auction with two (bankable) vintages. They find that the simultaneous clock auction shows desirable efficiency properties and outperforms alternative mechanisms if demand is elastic. This confirms our conjectures underlying the recommendations to the NETT in 2007.

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[12] The difference of the prices of coal and gas, for example, are one major driver of the price of an emissions permit as a fuel switch from coal to gas is an important abatement measure.

[13] Holt et al. (2008) undertake many experiments to test the auction design for the RGGI scheme. However, auctioning different vintages (multi-items) was not tested.

More recently, Ausubel *et al.* (2009) experimentally test sealed-bid and clock auctions in a setting where bidders have additional side constraints, such as budget constraints or liquidity needs. This work also supports our main recommendations.

4. Goals of the auction

The Australian Government's (2008) CPRS White Paper states with regard to the goals of the auction (Commonwealth of Australia 2008, p. 9-2): "The Government considers that the key objectives are as follows:

> Promote allocative efficiency. (…)
>
> Promote efficient price discovery. (…)
>
> Raise auction revenue (consistent with other objectives). (…)"

The primary objective is to ensure that permits are allocated efficiently, meaning that they flow to the bidders who value them the most. As mentioned in the introduction, it is the main advantage of running auctions that the resulting allocation is likely to be more efficient than any other administrative allocation mechanism. However, even by means of an auction, reaching efficiency is a challenge in a multi-unit context. In most formats (e.g. pay-your bid and uniform auctions), bidders will shade their bids, i.e. the bids will understate the true marginal valuations. Particularly if bidders are non-symmetric, to some extend inefficiency is likely. Other formats like VCG approaches offer efficient outcomes – at least in a private value context – but are difficult to implement and challenging to communicate.

By generating price signals, auctions address the second objective to reveal marginal abatement costs. A well designed auction mechanism aggregates the beliefs of all participants regarding the value of the permits. This reduces the planning uncertainty and provides valuable information to decision makers regarding investments into abatement measures. Clearly, a free allocation procedure does not provide this information. However, different auction formats vary as well regarding the information they provide.

Finally, raising public revenue by means of an auction is generally less harmful to economic activity than taxes on profits, which lead to so-called deadweight losses (cf. e.g. Ballard *et al*., 1985 or Feldstein, 1999). Auctions have the additional advantage over free allocation procedures that they generate public revenue. Thereby they offer the potential to reduce taxes and the distortions induced by them (Goulder 1995). In cases where the revenue raising objective conflicts with allocative efficiency and price discovery, the White Paper clearly indicates that the two latter objectives should be given priority over revenue.

5. Auction design

In this section the characteristics of our recommended and subsequently by the White Paper adopted auction format is described in more detail.

5.1 The ascending clock auction

An ascending clock auction resembles an English auction. Different to the open-outcry format often used by auction houses, in the ascending clock variant, it is only the auctioneer who controls the pace of the auction. Over several rounds, he announces a *current price* that he increases from round to round and bidders indicate their willingness to acquire the item at this price. Once a bidder declines the offer in a particular round, she cannot re-enter the auction again in a later round. In a single-item application, the auction stops as soon as only one bidder remains and the price to pay is the price of either the last or the second to last round.

In a multi-unit extension, prior to the start of the auction, the auctioneer determines and announces the total available quantity (supply s) and a reserve price p_0. The auctioneer then opens the auction ($t = 0$) by inviting all bidders $I = 1, 2, \ldots n$ to each submit a bid $d_i(p_0)$ that specifies the quantity of units (demand) the bidder wishes to acquire at the reserve price. If the total demand is not larger than the total supply (i.e. $_i\ d_i(p_0)$ s), the auction ends. All bidders receive the units they requested and have to pay the reserve price for each unit obtained. Any remaining supply is not sold.

If the total demand exceeds total supply, the auctioneer increases the price and opens a new round $t := t + 1$ of bidding. The new price is indicated by p_t. Again, the bidders respond by submitting their demand $d_i(p_t)$ at this price. This process continues as long as the total demand by all bidders exceeds the offered supply. As the announced *current price* p_t increases from round to round ($p_t > p_{t-1}$), bidders cannot increase their demand ($d_i(p_t) \leq d_i(p_{t-1})$). Thus, the total demand is sloping downward over the course of the auction.

The auction ends once the total demand is no longer larger than the supply being auctioned. If the total demand in the last round t^* exactly equals supply ($\sum_i d_i(p_{t^*}) = s$), then the final price p^* is set to the last round's current price ($p^* := p_{t^*}$) and all bidders i receive the quantity $d_i(p_{t^*})$ they requested in their last bid. If, alternatively, total demand in the last round t^* is lower than the supply, the final price p^* is set to the price of the second to last round t^*-1 ($p^* := p_{t^*-1}$). Again, all bidders are awarded the quantity $d_i(p_{t^*})$ demanded in their last bid. In addition, the residual supply $s - \sum_i d_i(p_{t^*})$ is allocated to the bidders in equal proportions to the residual demand with respect to the bids $d_i(p_{t^*-1})$ in the second to last round. This means that a particular bidder j receives in addition to $d_j(p_{t^*})$ units an amount given by

$$\left(d_j(p_{t^*-1}) - d_j(p_{t^*})\right)\frac{s - \sum_i d_i(p_{t^*})}{\sum_i d_i(p_{t^*-1}) - \sum_i d_i(p_{t^*})} \quad .$$

This closing rule ensures that the total supply is exactly allocated among the bidders.[14]

[14] The following example illustrates the closing and pricing rule. Assume a total supply of 100 units is auctioned. There are two bidders A and B. In the second to last round A submits a bid of 70 units and B a bid of 40 units, and in the last round A bids 61 and B 34. Both bidders are awarded the quantities specified in their last bid. Since these bids add up to 95 units, there is a residual supply of 5 units. Based on the bids of the second to last round, A has a residual demand of 70 – 61 = 9 units and B a residual demand of 40 – 34 = 6 units and the total residual demand is 15. Thus 5 / 15 = 1/3 of the residual demand is served and A receives a total of 61 + 9/3 = 64 units and B a total of 34 + 6/3 = 36 units.

5.2 Uniform pricing

The recommended auction design applies a uniform pricing scheme that provides a strong signal regarding the participants' aggregated estimates of the true future value of a permit. A caveat is that the uniform pricing scheme also raises the incentive for bid shading and demand reduction. In particular, if a few large bidders dominate the market, the resulting price is likely to understate true marginal abatement costs. However, analysis of the Australian electricity market confirms that no participant has a market share greater than 15%.[15] As a consequence demand reduction is expected to have only a minor impact if at all.

5.3 Information revelation

In principle conducting an ascending clock auction provides several options for information revelation:

After each round the auctioneer could:

- indicate only whether total demand exceeds supply and whether an additional round of bidding will be conducted; or
- publish the total demand which has been submitted; or
- publish the number of active bidders; or
- reveal every individual bid.

Publishing the total demand at the end of each round improves transparency and increases the information available to participants. This information reflects the aggregated (reported) demand curve and relates to the economy's abatement cost curve. To the extent that bidders

In case the result would be that one unit would need to be split, it will be randomly decided which of the bidder receives the unit.

[15] Of the 57 electricity generating companies in Australia, the five highest emitting companies account for approximately 50% of emissions and the ten largest for 81%. The Herfindahl-Hirschmann-Index (HHI) of the electricity generating market - which measures market concentration - was found to be 0.075. A HHI index of 0.075 is considered to be low, and thus indicative of an un-concentrated market (Evans and Peck 2007).

shade their bids, the reported demand understates the abatement costs. However it still provides valuable information for planning purposes and re-evaluation of individual business assessments.

A contrary argument is that by revealing the total demand, participants are in a better position to estimate the final price of the auction before it actually closes. This guides bidders regarding optimal bid shading and may result in more heavily shaded bids and stronger demand reduction.

On balance, we believe that revealing total demand at the end of each round will result in better outcomes.[16] This information will help bidders in refining their future bids. We also consider the likelihood that the recommended multiple round ascending clock design performs as well or better than a static uniform price auction in which bidders face greater uncertainty as to the future market price of an AEU.

Similarly, one could argue that publishing all individual bids at the end of each auction round, might be even more beneficial for both the bidders and the auctioneer. This alternative, however, is not favoured for the following reasons:

> The potential value of this information revelation is rather weak (What can actually be deduced from knowing that a specific bidder drops out at a certain price?);
>
> It adds unnecessary complexity to the mechanism as the number of bidders will be large and the auction conducted in a relatively short time frame;[17] and
>
> Publishing all individual bids may facilitate collusive behaviour, resulting in low revenues and poor efficiency.

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[16] In fact, if the aggregated demand were not revealed at the end of the auction, the auction would be equivalent to a sealed-bid uniform price auction. The advantages of the open procedure would then vanish.

[17] If all individual bids are revealed, the information flow is tremendous and it is unlikely that bidders will be able to extract valuable information from individual bids in such time intervals. Moreover, small bidders that cannot invest in excessive bidding support systems might be disadvantaged.

The Evans & Peck report recommended that – in addition to announcing the aggregated demand at the end of each round – all individual bids be published after the closing of an auction. The White Paper adopted our recommendation to reveal the aggregated demand at the end of each round. It is not specific whether individual bids will be published.[18]

5.4 Proxy bidding

Even though a clock auction can be conducted in a single day with just a handful of rounds, a small bidder may prefer to submit a single demand curve to be used throughout the auction, rather than participate explicitly in each round. Similarly, a bidder may not want to closely follow the auction at all times, but be allowed to be absent for some time without disadvantage. For this reason, it is recommended that the auction allows and supports tools for proxy bidding.

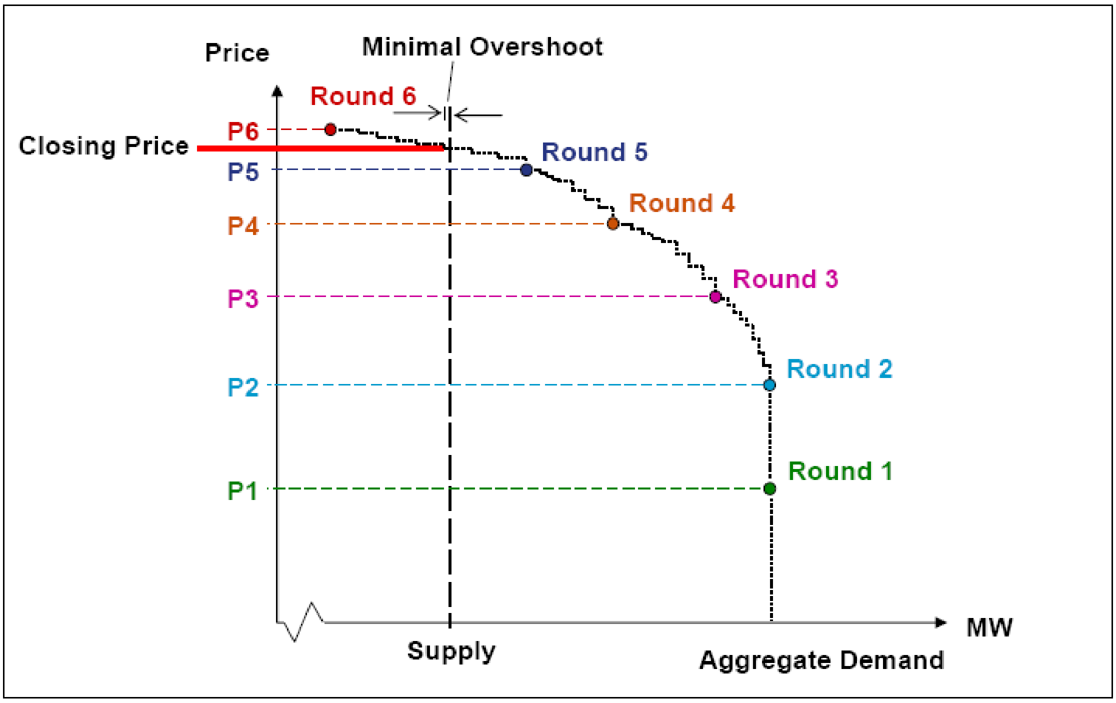
In the ascending clock auction a proxy bid is a demand curve specified by the bidder and submitted to the system. The system then automatically bids on behalf of the bidder according to her proxy bid. Thus, bidders can treat the auction as a uniform-price sealed-bid auction not taking advantage of the information published in each round.

5.5 Intra-round bidding

A desirable option is to augment the recommended auction mechanism described above with intra-round bidding (Ausubel and Cramton 2004). This is an alternative to the rationing approach to resolving residual demand when the auction fails to clear the market perfectly. With intra-round bidding, the possibility of bidders overshooting the market clearing quantity from the second-to-last round to the last round is avoided by having bidders submit intra-round bids. In each round bidders privately submit their demand schedules indicating the

[18] In the context of information revelation at the end of each round, the White Paper rules that individual bids will not be revealed in order to avoid collusion (p. 9-28). With respect to publication of auction results it states that the results will be published in a timely fashion without being specific on what these results are (p. 9-29).

quantity they demand for every price between the previous and current round. Thus, if demand falls short of supply as the clock ticks from the second last to the final round, then the auctioneer will aggregate the inter-round bids to find the price at which supply exactly equals demand.



(P. Cramton, presentation at CEEM Expert Workshop on Auctioning, 2007)

By using this implementation mechanism the market therefore clears perfectly at the market-clearing price and there is no need for rationing residual demand among winning bidders.

Therefore intra-round bidding is a tool to smooth the clearing process. It has the advantage of minimising the importance of rationing (tie-breaking) and it enhances auction efficiency. Intra-round bids may even increase revenue. Moreover, with intra-round bids allowed, the auctioneer may choose to use larger bid increments and thereby speed up the auction process. The potential downside of the latter option is that larger bid increments reduce the number of auction rounds and thus reveal less information to the bidders.

Intra-round bidding is used in the majority of high-stake clock auctions. Bidders find the approach easy to understand, and its implementation is simple for the auctioneer (Ausubel and

Cramton 2004). Moreover, while bidders can take advantage of intra-round bidding, they are not required to do so. Intra-round bidding was therefore recommended for the Australian auctions.

5.6 Auctioning different vintages

In order to create early price signals advance auctions were suggested. This means that the permits of one vintage are auctioned in several charges at different points of time – some of them several years ahead of the respective vintage. As a consequence, different vintages will be auctioned at the same auction event.

Since emissions permits of consecutive vintages are close substitutes, the auction system should provide the flexibility to switch among different vintages. A sequence of individual auctions, for example, does not support this feature and does not ensure that similar items sell for similar prices.

Instead, simultaneous auctions have proven very successful in such situations (cf., e.g., Cramton 1997). Simultaneous auctions allow bidders to shift demand from one item (vintage) to another as long as the auction runs, and the auction will close only if there is no longer activity on *any* item. These simultaneous formats have become famous in the FCC spectrum auctions, but have been used in many different – often very large scale – contexts since. Thus, simultaneous ascending clock auctions have been recommended for auctioning several vintages in the context of the Australian CPRS.

5.7 Double auction extension

Some permits will be awarded to companies of the EITE sector which may not be directly liable under the scheme and therefore have a valuation of zero for the AEUs. Thus, if the free allocations are known before an auction starts, there could feasibly be both net buyers and net sellers. Net buyers are those companies that have a residual demand and wish to acquire additional AEUs in the auction; net sellers are those companies that have more AEUs than they will actually use themselves. Some EITE companies will probably be net sellers.

If only the government sells permits in an auction, only those companies which have relatively high abatement costs have an incentive to participate in the auction; net sellers like EITE companies are not expected to participate. Thus the companies that will participate in the auction represent a biased sample of all companies involved in the CPRS. If bidders do not take this issue appropriately into account, the auction will be more competitive than the later secondary market leading its closing price to overestimate the future development of the market price: the resulting allocation may be inefficient (Benz and Ehrhart 2007).

For this reason, it is appropriate to extend the auction format in a way that allows companies, which already possess emission permits, to sell these permits in the auction. The auction then takes on the characteristics of a double auction. This adds some complexity, but has the advantage that the double auction format is likely to result in a more efficient outcome. Transaction costs for net sellers will be low compared to the secondary market. As a consequence of a less biased sample of participants the auction will generate more reliable price signals than its one-sided counterpart. Finally, the non-vertical supply curve also reduces the incentives for demand reduction.

As extending the auctions to a double or two-sided format is expected to increase efficiency, the government should create an incentive for participation by not charging the sellers transaction fees.

5.8 Frequency and timing of auctions

In order to generate an early price signal, the first auction needs to take place before the start of the scheme. In additions to spot auctions we recommend so called advance auctions as they set early price signals for the future and ensure that permits are in circulation before the compliance year for which they are valid. This gives a greater certainty to investors interested in investing in infrastructure with longer lead times and long life times. Trading permits of future vintages compared to trading futures or forwards has the advantage that those permits can be traded spot without any risk premium. Buying permits at the advance auction will only cause holding costs since the capital is bound and cannot be used elsewhere. To set a price signal for the future it is not necessary to auction permits for each future vintage, but it seems sufficient to auction only individual vintages as was practiced under the US Acid Rain programme (Montero and Ellermann, 1998). Furthermore, it may not be efficient to auction vintages far into the future as it is questionable whether companies will be able to predict accurately what their abatement costs will be in the far future many years before actual abatement is set to occur. Therefore it is recommended that the advance auctions be oriented around the timing of investment decisions for abatement measures. Such measures generally have a lead time of up to three years before they become effective. Advance auctions should be run a maximum of three years in advance, to allow progressively more accurate information to become available.[19]

Together with the decisions regarding timing and auctioning of vintages, the frequency of auctions should also be assessed. A discussion of advantages and disadvantages of more or less frequent auctions can be found in Neuhoff (2007).

On balance, frequent auctions have more advantages so quarterly spot auctions were recommended to the NETT. However, the auction share according to the White Paper is now higher than the former indications given by the NETT to the authors. Therefore the White Paper now foresees monthly instead of quarterly auctions. As vintages are auctioned three years in advance and there is one auction in the reconciliation period 16 auctions of one vintage will take place and in each auction 1/16th of the auctioning share of a vintage is auctioned. Some auction dates will include simultanious auctions of spot and advance

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[19] Such time frames are also common on the electricity market. Power generators typically forward contract for selling power on a time horizon out for five years. Forward contracts progressively diminish from a high contracted proportion for the immediate years to a high spot proportion five years out. A liquid secondary market is likely to be the most useful resource for electricity generators seeking to manage future needs for emission permit supply with auctions acting as the mechanism for getting supply onto the market in the first instance.

auctions (a maximum of four simultanious auctions are porposed in the White Paper) as it would increase efficiency and reduce transaction costs. Concentrating the advance auctions in one annual auction will reduce costs as companies do not need to learn how to bid in this more complex auction forms if they whish not to. However, those mutiple vintage auctions dates become more important compared to the other auction dates and may gain more attention by the managment of companies.

6. Conclusions

Based on the policy framework and theoretical as well as experimental findings mentioned above, an auction format with the following characteristics was recommended:

- ascending clock auction with iterative sealed-bidding in multiple rounds,
- uniform pricing,
- aggregate demand revealed in each round,
- simultaneous auctions of different vintages whenever applicable,
- allow EITEIs and other recipients of free permits to sell these permits in the auction (double auction extension),
- proxy bids to accommodate small participants,
- intra-round bidding and
- internet auction platform.

Auctioning design depends on the given ramifications and the characteristics of the product. The proposed auction design was specified for the Australian CPRS. It would need to be adapted to major changes in the ETS design such as the concept of permits as vintages or a reduced coverage which would impact on market power issues.

A remaining challenge of the proposed design lies in the complexity of bidding in multi-clock auctions (up to 4 simultaneous clocks one spot and 3 advance auctions are suggested in the

White Paper). Potentially, the multi-clock setting could lead to large shifts of demand from one clock to another. If all bidders just place their entire demand on the cheapest vintage, only one clock will tick forward in each round which would significantly slow down the speed of the auction. The issue can easily dealt with by an appropriate incrementing rule or some limitations in the shift of demand.

Given the trade-off between complexity and efficiency of running simultaneous clock auctions and the limited experience which exists today with regard to this particular auction approach, laboratory experiments prior to running the auction are recommended. They may not only be beneficial to spot potential problematic issues of the design but also to test the software. Therefore we recommend testing the auction in lab and field experiments before its actual implementation.

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