The Australian Journal of
Agricultural and
Resource Economics

Journal of the Australian Agricultural and Resource Economics Society

The Australian Journal of Agricultural and Resource Economics, 54, pp. 219–238

Auctioning greenhouse gas emissions permits in Australia*

Regina Betz, Stefan Seifert, Peter Cramton and Suzi Kerr†

The allocation of permits is an important design aspect of an emissions trading scheme. Traditionally, governments have favoured the free allocation of greenhouse gas permits based on individual historical emissions ('grandfathering') or industry benchmark data. Particularly in the European Union (EU), the free allocation of permits has proven complex and inefficient and the distributional implications are politically difficult to justify; auctioning emissions permits has therefore become more popular. The EU is now moving to auction more than 50 per cent of all permits in 2013, and in the US the Regional Greenhouse Gas Initiative (RGGI) has begun auctioning more than 90 per cent of total allowances. 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 the proposed Australian CPRS's auction design. A major difference to other emissions trading schemes is that the CPRS plans to auction multiple vintages of emissions permits simultaneously.

Key words: auctions, climate policy, emissions trading, greenhouse gases.

1. Introduction

Over the last few years, political interest in auctioning emissions permits has grown. The traditional free allocation process is plagued by windfall gains to emitters, as reflected in the EU experience (Sijm *et al*. 2006), and the inevita-

* This article is based on a project that was commissioned by the National Emissions Trading Taskforce (NETT) in 2007. The NETT was institutionalised by the Australian State and Territory Governments in 2004 in order to develop a multi-jurisdictional emissions trading scheme. The authors of the article were part of a consortium that was engaged to provide the NETT with detailed qualitative input on the auction design. In its 2008 White Paper, the new Federal Government adopted most of our recommendations for the auctions (Commonwealth of Australia 2008). The authors thank Evans & Peck for managing the project, Karl-Martin Ehrhart for fruitful discussions, as well as Ritwik Bose and Oli Sartor for research assistance. They also thank the participants of the 2007 workshops on permit auctions organised by the Centre for Energy and Environmental Markets at the UNSW. Support from the Environmental Economics Research Hub financed by the Commonwealth Environmental Research Facilities (CERF) and the Economics Design Network is gratefully acknowledged. The authors would also like to thank three anonymous referees as well as the editor for valuable suggestions that helped to improve the paper.

† Regina Betz (email: r.betz@unsw.edu.au) is at the Centre for Energy and Environmental Markets (CEEM), School of Economics, University of New South Wales (UNSW), Sydney, New South Wales, Australia. Stefan Seifert is at the Karlsruhe Institute of Technology, Karlsruhe, Germany. Peter Cramton is at the University of Maryland, College Park, Maryland, USA. Suzi Kerr is at the Motu Economic and Public Policy Research, Wellington, New Zealand.

doi: 10.1111/j.1467-8489.2010.00490.x

bly contentious debate about who should get the permits. Most notably, environmentalists have criticised the free allocation of permits as a transfer from the public to the emitting companies, contending that these transfers increase with the size of the company's past and/or expected future emissions. From a social perspective, consumer protection agencies have argued that consumers are unfairly burdened with the (opportunity) costs of emissions permits, which are factored into the power companies' tariff calculation 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 inefficient, at least temporally before secondary market trading occurs, as it cannot guarantee that it will allot the permits to those who value them most, i.e. those with highest abatement costs. Second, an auction – if appropriately designed – can serve as a mechanism to elicit the market value of an item. This aspect is particularly important in an emissions trading scheme, because many abatement measures require long-term planning and need years before they become effective. The 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 which measures are economically efficient. Third, auctioning emissions permits generates public revenues that are less disruptive of economic efficiency than taxes on profits or income.[2] Moreover, these proceeds partly offset the aforementioned shift from the consumer to producer surplus and can be used to counter regressive impacts.[3]

This study provides a comprehensive review and discussion of the Australian Carbon Pollution Reduction Scheme's (CPRS) auction design. It draws on lessons from auction theory and experiments as well as the authors' experience with practical applications of large-scale auctions. The paper also explains the particularities of the Australian emissions trading scheme with regard to auctions and summarises the auction proposal of the CPRS as laid out in the White Paper (Commonwealth of Australia 2008). Section 2 gives an overview of the CPRS design elements relevant for the auction; Section 3 discusses the relevant theoretical, experimental and empirical literature. In Section 4 the goals of the auction are presented, while Section 5 outlines the

[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).

[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) have argued that low-income households bear a larger relative burden of a cap on emissions than high-income households because they spend a higher share of their income on emissions intensive goods such as electricity. Furthermore, low-income households do not benefit as much from the higher share values occasioned by the free allocation of permits because shareholders are mainly high-income households, and the regressive effect is thereby reinforced.

details of the auction design envisaged in the CPRS White Paper. Section 6 assesses the interaction of primary and secondary markets; Section 7 concludes the paper.

2. Background on the proposed Australian emissions trading scheme

The CPRS legislation was introduced twice into the Australian parliament in 2009, but remains unpassed at the time of this writing. The legislation does not describe the auction procedure in depth and gives few details about the auction design itself. The most comprehensive information on the planned auction design is outlined in the White Paper (Commonwealth of Australia 2008). The main features of the CPRS based on the CPRS Draft Legislation (Australian Government 2009) can be summarised as follows:

- The CPRS is supposed to cover around 70 per cent of Australia's greenhouse gas emissions, which will include a wide range of emitting sources (e.g. from the electricity industry to the transport sector); some of them will be covered downstream, some upstream.[4]
- The scheme is scheduled to start on 1 July 2011.
- In the first year (2011–12), permits can be acquired at a fixed price of $10/t CO_2 equivalent.[5] There will be no cap on permits and permits cannot be carried over to future periods, i.e. banking will not be allowed (Australian Government 2009).
- Full trading will start in 2012–13. Permits from 2012 to 2013 onwards – so-called Australian Emissions Units, (AEU) – will be date-stamped (vintages) and bankable. In other words, if an AEU is not being used for compliance in a given year, it can be banked for the future without restrictions; moreover, a small share of borrowing is foreseen (5 per cent of future vintages can be used before they become valid).
- For the first 4 years of the trading scheme (2012–13 to 2015–16), a price cap will be introduced. This cap will start at $40 and increase each year at a real rate of 5 per cent. The future shape of the permit price cap will be discussed at the first independent review.[6]
- Some permits will be allocated for free to so-called 'strongly affected' industries (e.g. coal-fired electricity generators) as well as Emissions-Intensive and Trade-Exposed (EITE) Industries; EITE are to receive free allocations based on output data multiplied by a benchmark.[7]

---

[4] A *downstream* approach requires fossil fuel users to acquire emission allowances, whereas an *upstream* approach requires permits to be acquired by the fuel producers.

[5] In this paper, unless specified otherwise, all dollars refer to Australian dollars.

[6] The impact of the price cap on efficiency, effectiveness and fairness is discussed in Jotzo and Betz (2009).

[7] For details on allocation rules for EITE industries, see the White Paper and accompanying documents: http://www.climatechange.gov.au.

- Auctioning permits will start with the vintage 2012–13 and the first advance auction of this vintage is scheduled to be held before the start of the scheme. We estimate that the auction share will be more than half of the AEUs of any given vintage. The share may fluctuate over time with changes in the output of EITE sectors or in case the coverage is extended.[8]
- Permits have to be surrendered on the basis of annual monitoring and reporting.
- One-sided international linkages to include other eligible international units (as stipulated in part 1, Section 5, p. 11 of the CPRS Bill 2009) will be made possible, such as the unlimited use of the Clean Development Mechanism and Joint Implementation. The export of AEUs, however, will not be allowed.

As in the EU, an AEU allows its owner to emit one tonne of CO_2 equivalent. Whereas a European Union Allowance is valid for a given compliance period (e.g. 5 years for Phase II, 8 years for Phase III), Australia plans to have a finer granularity. As indicated before, each AEU will have a date stamp (vintage) indicating the year in which it will become valid. (For example, an AEU with a vintage of 2014/15 will only become valid from July 2014 onwards and cannot be used for compliance in the first 2 years of the CPRS, i.e. 2012/13 and 2013/14). Inter-temporal flexibility is limited to the possibility of unrestricted banking (e.g. any surplus of AEUs can be carried over to future periods to be used for compliance) and some limited share of borrowing (e.g. 5 per cent of 2014/15 vintages can be used for compliance in the year 2013/14).

Thus, emissions permits of different vintages are interchangeable in certain circumstances: A permit of an earlier vintage can always substitute for a permit of a later vintage. The reverse is not true: only up to 5 per cent of a year's emissions can be covered by permits of a future year. Two permits of the same vintage are always perfect substitutes, of course.

With respect to production technologies and long-term abatement measures, 1 year is a rather short time frame. As far as investments in 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 permits that are subject to long-term emissions management approximately concurrently with the investment decisions. The allocation of permits that concern short-term fluctuations (e.g. in energy consumption) however, could occur later. This suggests that it does not make sense to allo-

[8] There is no auction share published in the White Paper and data for EITE industries are not available on the disaggregated level, so it is not possible to actually calculate the amount of the free allocation. We therefore used the free allocation share of 25 per cent cited in the White Paper for EITE industries and the published number of free permits to strongly affected industries (which was converted to around 6 per cent). This results in an auction share of around 70 per cent. However, according to the announced changes in 2009, such as the Global Recession Buffers, a longer allocation of free permits to strongly affected industries (10 instead of 5 years) will reduce this amount.

cate all permits of the same vintage at the same time. On the other hand, it follows that at a particular point in time permits of different vintages might be allocated simultaneously. An appropriate auction design should take this latter aspect into consideration and provide some flexibility. For example, if a bidder seeks to acquire permits of a particular vintage, but an earlier vintage is available for less, he should be allowed to buy the earlier vintage because it serves the same purpose (this can be difficult to arrange if auctions are held sequentially and/or are sealed, however). Moreover, the auction should generate a price structure that yields valuable information with respect to the expected scarcity of permits in the future.

3. Related literature

The early literature on tradable permit systems (e.g. Dales 1968) typically assumed that permits were 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 in achieving acceptance for auctioning, might explain why auctions have rarely been used in actual environmental markets. Established schemes that did apply auctions, such as the Acid Rain program or the NO_x trading system in the US, auctioned only a small share of the total allowances (e.g. Cason and Plott 1996; see also Evans and Peck 2007). Therefore, the empirical literature in fact provides very little empirical information on permit auctions.

Within the EU Emissions Trading System (ETS), the auction share was limited up to 5 per cent in Phase I (2005–7) (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 mio. t of CO_2e per year, or 0.2 per cent of the entire ET budget in the first phase (Betz *et al.* 2006). In Phase II (2008–12), the auction share was limited by the Directive (CEC 2003) to go up to 10 per cent. Only six of the 27 European Union Member States have chosen to auction allowances in this phase.[9] Up to now, the dominant auction format in the EU has been the uniform-price sealed-bid auction, whereby all auctions have set a minimum price and succeeded in generating prices around the secondary market price.[10] In Phase III, the adopted Directive (CEC 2009) foresees a much higher share of auctioning. Auctions will be the dominant

[9] Total amount to be sold or auctioned is around 3% of EU-budget 2008-2012. The following countries are auctioning or selling allowances (based on National Allocation Plan data): Germany (9% or 40.0 Mio. EUA/a around 60% of total auctioning amount of EU), UK (7% or 17.2 Mio. EUA/a), Netherlands (3.7% or 3.2 Mio. EUA/a), Lithuania (2.8% or 0.5 Mio. EUA/a), Hungary (2.7% or 0.5 Mio. EUA/a), Austria (1.3% or 0.4 Mio. EUA/a). Two countries are selling: Ireland (0.5% or 0.1 Mio. EUA/a) and Denmark (0.3% or 0.1 Mio. EUA/a).

[10] Fazekas (2008) has reported that most countries (apart from Ireland) started auctioning 'too late', i.e. they auctioned only after the drop of permit prices in May 2006 and therefore missed out on the earlier high prices.

allocation method for the electricity sector and will become more relevant for other sectors as free allocation is gradually phased out by 2027 (with the exception of 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 market, the auction design may differ from that of the CPRS. For example, the current design in the UK for Phase II is a uniform-price sealed-bid auction.

The only emissions trading scheme with a substantial share of auctioning (more than 90 per cent) is the Regional Greenhouse Gas Initiative (RGGI) in the US. It also employs uniform-price sealed-bid auctions. Again, the units differ from those of the CPRS in that they have compliance periods of 3–4 years. In the RGGI, auctions were initiated in September 2008. Current vintages are auctioned along with one future vintage from the next compliance period (RGGI 2008). The total share one participant can bid for is capped at 25 per cent of total permits and 100 per cent financial insurance is required for all bids. The auctions are held separately, bids are handed in sequentially, and the results of the auctions are revealed only after both of them have been closed. The experience of the first four auctions has shown that the auction price was usually a better predictor of the underlying market trend than other secondary market prices. The auctions have generally been competitive (with around 45 bidders in the current vintage and around 12 bidders in the future vintage).[12]

So far, the empirical literature on permit auctions has not yet reported on experience with simultaneous clock auctions. We will therefore move on to review the theoretical and experimental literature.

There is a rich body of literature on multi-item and multi-unit auctions, both theoretical and experimental. The theoretical analysis of auctions is rather straightforward if we restrict our attention 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 that occur 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 in a multi-unit demand scenario bidders tend to bid rather defensively compared to their (marginal) valuations. As a result, the outcome of multi-unit auctions can well be inefficient.

A further generalisation can be drawn from auctions of multiple heterogeneous items. A rigorous analysis is given e.g. in Armstrong (2000). The assumptions of the underlying economic situation are very basic, however, as

[11] Emissions leakage can occur when there is 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 country.

[12] This information is based on a presentation by Bill Shobe at the Centre for Energy and Environmental Markets, UNSW in October 2009.

Armstrong considers items with independent valuations. More realistic are situations in which the valuations of the items put up for auction are characterised by interdependencies, either complementarities (a bundle of items is worth more than the total value of the individual items) or substitutability (a bundle is worth less than the sum of the values of its individual items). Bidding now becomes more complex, and additional difficulties, such as the exposure problem, may arise. The literature focuses on bundle bids and efficiency, often benchmarking possible auction formats with the Vickrey-Clarke-Groves (VCG) mechanism, an extension of the Vickrey auction (Vickrey 1961) for multi-item situations. For combinatorial reasons, however, bidding in a VCG auction is difficult and even infeasible if there are a large number of items. For an overview of combinatorial auctions, see Cramton *et al*. (2006).

Most of the papers described above investigate auctions in which the bidders have private valuations of the objects, i.e. 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, though, because bidders face uncertainties about the development of abatement technologies, future demand for their products, or the future prices of alternative fuels.[13] When it comes to multi-unit demand with uncertain valuations, the theory is much less developed (see e.g. Ausubel 1999), but there is virtually nothing in the literature on auctions in which different types of items (e.g. different vintages in the emissions permits context) and many units (AEUs) are involved. Thus, a theoretical approach to the problem at hand does not seem feasible.

Similarly, the experimental literature does not specifically address 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 *et al*. (2006) experimentally compare the static Vickrey auction with a dynamic variant (Ausubel 2006). The experiment is interesting insofar 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 one of the only experimental works to address the interaction between multi-unit and multi-item aspects of different auction types.[14] They experimentally compare clock auctions and a sealed-bid auction in both a simultaneous and sequential setting in which multiple units of two different items are offered. Moreover, the context is very similar to the AEU auction in that Porter *et al*. investigate potential designs for the Virginia NO_x auction with two (bankable) vintages. They find that the simultaneous clock auction has desirable efficiency properties and outperforms alternative

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

[14] Holt *et al*. (2007) have conducted many experiments to test the auction design for the RGGI scheme. However, auctioning different vintages (multi-items) was not tested.

mechanisms if demand is elastic. This confirms our conjecture underlying the proposed CPRS auction design.

More recently, Ausubel *et al.* (2009) have experimentally tested sealed-bid and clock auctions in a setting where bidders had additional side constraints, such as budget limitations or liquidity needs. Their findings also support the proposed CPRS auction design.

To conclude, none of the existing literature (empirical, theoretical and experimental) explicitly addresses simultaneous auctions of multiple permit vintages, which is an important feature of the proposed Australian CPRS auctions.

4. Goals of the auctions

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

- Promote allocative efficiency (…) with a minimum of risk and transaction costs.
- 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. Minimising risk (e.g. market power or collusion) and transaction costs are part of this objective. As mentioned in this paper's introduction, the main advantage of running auctions is that the resulting allocation is likely to be more efficient than any other administrative allocation mechanism. However, even if an auction is used, achieving 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, some degree of 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 to participants.

By generating price signals, auctions address the second objective, which is to promote efficient price discovery. A well-designed auction mechanism aggregates the beliefs of all participants regarding the value of the permits. This reduces planning uncertainty and provides valuable information to decision-makers concerning investments in abatement measures. Clearly, a free allocation procedure does not provide this information. However, different auction formats also differ in the information they provide.

Finally, permit auctions have the additional advantage over free allocation procedures in that they generate public revenue. This means of raising revenue 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). Thus, permit auctions, like carbon taxes, offer the potential to reduce other taxes (such as existing taxes on profit or labour) and the distortions induced by them (Goulder 1995). Alternatively, auction revenues can be used to finance government investments that yield other payoffs (e.g. research to improve health) or to reduce the debt burden. However, as Hahn (2009) has pointed out, there is little evidence to suggest that auction revenues are in fact used in the described ways. It is more likely that they will be earmarked to encourage related efforts, such as further reducing emissions or for compensation measures. The Australian government proposes in the White Paper that the auction revenue be used to compensate industry and households for the impact of the scheme and to finance information and structural adjustment provisions.

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 the auction format adopted in the White Paper are described in more detail.

5.1 The ascending clock auction

An ascending clock auction resembles an English auction. In contrast to the open-outcry format often used by auction houses, however, in the ascending clock variant, it is solely the auctioneer who controls the pace of the auction. Over several rounds, he announces a *current price,* which 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 must withdraw and 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. He 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 they wish to acquire (demand) at the reserve price. If the total demand is not larger than the total supply (i.e. $\sum_i d_i(p_0) \leq s$), 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 slopes 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

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

This closing rule ensures that the total supply is exactly allocated among the bidders.[15]

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. One 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 the true marginal abatement costs. However, analysis of the Australian electricity market confirms that no participant has a market share greater than 15 per cent.[16] As a consequence, demand reduction is expected to have only a minor impact if at all.

[15] The following example illustrates the closing and pricing rule. Assume a total supply of 100 units to be 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. As 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, so the total residual demand is 15. Thus, 5/15 = 1/3 of the residual demand is served, with A receiving a total of 61 + 9/3 = 64 units and B a total of 34 + 6/3 = 36 units. In the event that one unit would need to be split, this unit would be randomly allocated to one of the two bidders.

[16] Of the 57 electricity generating companies in Australia, the five highest emitting companies account for approximately 50 per cent of emissions and the 10 largest account for 81 per cent. 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).

5.3 Information revelation

In principle, 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 that 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. Even if bidders shade their bids and the reported demand understates the marginal abatement costs, the total demand still provides valuable information regarding the scarcity of permits.

A contrary argument is that when the total demand is revealed, 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 the total demand at the end of each round will result in better outcomes.[17] This information will help bidders to refine their future bids. We also consider it likely that the multiple-round ascending clock design performs as well or better than a static uniform-price auction in which bidders face greater uncertainty vis-à-vis 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 recommended for the following reasons:

- The potential value of this 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; the number of bidders will be large and the auction will be conducted in a relatively short time frame[18]; and

[17] 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.

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

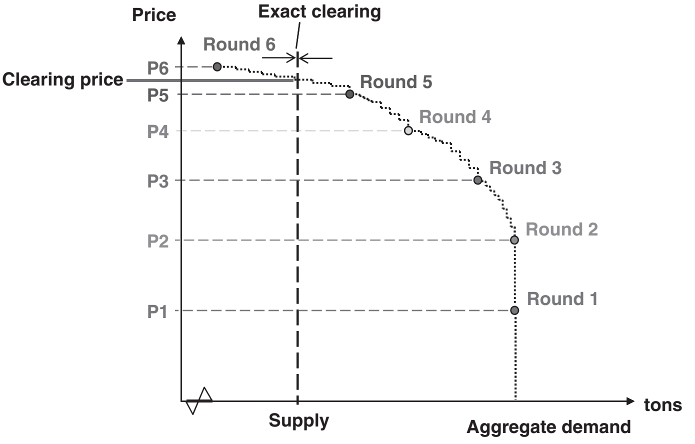

Figure 1 Aggregate demand with intra-round bids (P. Cramton, presentation at CEEM Expert Workshop on Auctioning, 2007).

- Publishing all individual bids may facilitate collusive behaviour, resulting in low revenues and poor efficiency.

The White Paper proposes that the aggregated demand be revealed at the end of each round. It does not specify whether individual bids will be published.

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 in each individual round. Similarly, a bidder might not want to closely follow the auction at all times, but be allowed to be absent for some of the time without disadvantage. For this reason, it is recommended that the auction allow and support tools for proxy bidding.

In an 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 making use of the information published in each round.

5.5 Intra-round bidding

A desirable option is to augment clock auctions with intra-round bidding (Ausubel and Cramton 2004). This is an alternative approach to resolving residual demand when the auction fails to clear the market perfectly. With intra-round bidding, the likelihood of bidders overshooting the market clearing quantity from the second-to-last round to the last round is reduced by having bidders submit intra-round bids. In each round, bidders privately submit their demand schedules indicating the desired quantity for every price between the previous and current round. Thus, if demand falls short of supply as the clock ticks from the second-to-last to the final round, the auctioneer will aggregate the inter-round bids to find the price at which supply exactly equals demand (Figure 1).

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

Intra-round bidding can therefore be considered a tool with which 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, intra-round bids allow the auctioneer 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. However, intra-round bidding is not explicitly mentioned in the CPRS White Paper for the Australian auctions.

5.6 Auctioning different vintages

The White Paper supports auctions of future vintages because they create early price signals. 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. To reduce the number of auctions different vintages will be auctioned at the same auction event.

As emissions permits of consecutive vintages are close substitutes, the auction system should allow bidders to switch among the different vintages. A sequence of individual auctions, for example, does not support this feature and will 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 became famous in the FCC spectrum auctions, but have been used in many different – often very large-scale – contexts ever 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 private 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. Some EITE companies will probably be net sellers.[19]

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 some EITE companies are not expected to participate. The companies that will participate in the auction therefore 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).[20]

In order to accommodate the net sellers of EITE companies, it is appropriate to extend the auction format in a way that allows companies which already possess emissions permits to sell these permits in the auction. The auction then takes on the characteristics of a double auction. This adds some complexity, but the double auction format is likely to result in a more efficient outcome, especially in early years when the secondary market may not be liquid. 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, in the event that the sellers can specify a supply curve, the non-vertical supply curve would also reduce the incentives for demand reduction. Overall, extending the auctions to a double or two-sided format is expected to increase efficiency.

[19] Aluminium smelters, for example, will receive free permits for their electricity use, which constitutes indirect emissions, and the permits for those emissions will be surrendered by the electricity producer that is selling the electricity to the aluminium smelter. As the aluminium smelter only has to surrender permits for its direct emissions, which are relatively low, they are likely to receive more permits than they will need. This means that some aluminium companies (the ones that do not have other installations with a net buying position) will be net sellers. This will most likely be foreign companies that only own aluminium smelters and no plants in other emission-intensive sectors in Australia, such as Norsk Hydro.

[20] However, this experimental study assumed that only companies regulated under the scheme can participate in the auction. In reality, the CPRS does not limit the participation to regulated companies. Speculators as well as investors may participate and will increase the competitiveness in the auction, thus reducing the risk of collusion.

5.8 Frequency and timing of auctions

In order to generate early price signals, the first auction needs to take place before the start of the scheme. In addition to current vintage auctions, so-called future vintage auctions are foreseen as part of the scheme because they will 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. Buying permits at the advance auction will only cause holding costs for the capital that 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. Rather, it seems sufficient to auction only individual vintages, which was done under the US Acid Rain program (Montero and Ellermann 1998). Furthermore, it might not be efficient to auction vintages far into the future, because companies most likely cannot accurately predict what their abatement costs will be in the distant future, i.e. many years before actual abatement is set to occur. Therefore, advance auctions should be oriented on the timing of investment decisions for abatement measures. Such measures generally have a lead time of up to 3 years before they become effective. Advance auctions should be run a maximum of 3 years in advance in order to allow progressively more accurate information to become available.[21]

Together with the decisions regarding the 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, auctions held during the fiscal year have advantages over yearly auctions. Correspondingly, the White Paper foresees monthly auctions.[22] As vintages are auctioned 3 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 will be auctioned. At some auction events, simultaneous spot and advance auctions will be conducted (up to five simultaneous clocks at the same auction event are foreseen in the White Paper: one for the previous vintage, one for the current vintage, and three for future vintages) in order to increase efficiency and reduce transaction costs. Concentrating the advance auctions in one annual auction will reduce costs because companies will not need to elaborate bidding strategies for these somewhat more complex auction forms for each auction event. Thus, the multiple vintage auction events will become more important compared to the other auctions and might draw more attention by the companies' managements.

---

[21] Such time frames are also common on the electricity market. Power generators typically engage into forward contract for selling electricity up to 3 years in advance.

[22] The Evans & Peck (2007) report argues in favour of quarterly auctions, assuming a lower auction share.

Table 1 Relationship between auction design and government's auction goals

Proposed auction design elements	Allocative efficiency (including risk of collusion)	Price discovery	Transaction costs
Ascending clock/uniform pricing	In the lab, open auctions tend to result in higher efficiency than their sealed-bid counterparts. Moreover, compared to traditional multiple ascending round auctions, the clock format limits the possibilities for signalling and thus reduces the risk of collusion	The uniform pricing of the ascending clock auction gives unique and thus strong price signals	A clock auction is intuitive and easy to understand. It also unfolds quite quickly even if the number of units being auctioned is very large. This keeps explicit and implicit transaction costs low
Information revelation (aggregate demand at the end of each round)	The iterated revelation of aggregated demand elicits a proxy of the society's abatement cost curve and thereby facilitates efficiency and price discovery		Simplifies bidding for small bidders who do not have resources for extensive studies on the society's abatement costs
Proxy bidding			Allows bidders to be absent from the auction
Intra-round bidding	Efficiently aligns supply and demand at end of the auction		Potentially increases the speed of the auction because bid increments can be larger
Simultaneous clock auctions	Reduces exposure risk and supports substitution of vintages	Allows switching among vintages (a special feature of the CPRS) and thereby facilitates bidding if valuations are interdependent	Reduces risk associated with valuations for bundles of permits
Double auction	Particularly in the early years, when some companies may be net sellers (e.g. EITE) and secondary markets are illiquid, a double auction may be more efficient, as the non-vertical supply curve reduces incentives for demand reduction	Generates more reliable price signals than one-sided auctions because all companies and agents can participate	Reduces transaction costs for net sellers compared to secondary markets

Note: The auction objective to generate revenue was not included in the table, as efficiency was given priority over revenue generation by the Australian government. In any case, where an auction is efficient, it is likely to generate higher revenues compared to an inefficient auction.

5.9 Auction design evaluation

Table 1 summarises the auction design elements and explains how each of the recommended features contributes to achieve the Australian government auction goals set out in Section 4. As the table shows, the strength of the proposed auction design is that it complies with the requirements of the Australian government. In particular, the benefit of an open clock auction seems important for price discovery in Australia, as liquid secondary markets might not exist at the beginning of the scheme. However, compared to the simple single-vintage sealed-bid auction format used in other schemes, the proposed design is rather complex. Also, the multi-clock setting could potentially lead to shifts of demand from one clock to another. If all bidders simply 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. This issue, however, can easily be addressed by an appropriate incrementing rule or restrictions on shifts of demand.

But this trade-off between efficiency and complexity has been addressed by the proposal by giving bidders a choice: Those who want a simple sealed-bid auction can opt for proxy bidding, while those wanting to use the additional information after each round can choose the clock option.

6. Interaction of primary and secondary markets

'Why bother with auctions at all?' is a valid question. In principle, the government could sell the permits on the secondary market instead.[23] In fact, such an approach was chosen in the EU ETS by for example Denmark in the first phase (Fazekas 2008) and by Germany from 2008 to 2010 (Deutscher Bundestag 2007, Article 21). The answer to this question depends on the liquidity, timing and maturity of the market as well as the quantities of permits to be sold.

A secondary market must exist before items can effectively be traded on it. If liquidity is very low, so that only the permits sold by the government are being traded, there would be no difference between a primary auction and a secondary market. Since in Europe a more or less liquid market for CO_2 permits existed in the phases mentioned above and both Denmark and Germany only sold small portions of their permits, these sales did not have a significant effect on the market. In Australia, however, liquid emissions permits markets do not yet exist.

An argument against holding frequent auctions is that doing so would reduce the liquidity of the secondary market (Diekmann and Schleich 2006; Neuhoff 2007). This may well be the case, particularly if large volumes are auctioned. On the other hand, the more efficient the initial allocation is, the

[23] An analysis of auctioning versus selling on the secondary market was undertaken for the UK government (Cook *et al*. 2005).

lower the need for transactions on the secondary market will be. Why not get the allocation right in the first place rather than delegate this task to the secondary market?

Furthermore, the main goal of the auctions is to discover marginal abatement costs. The earlier the cost information is revealed, the more valuable it is. This again calls for auctions whose timing can be explicitly set such that they provide for some initial allocation that will then stimulate secondary markets for fine-tuning. A stimulating effect has been observed by Neuhoff (2007). Based on their observations of the US T-Bond auctions, they found that secondary market activity increased when auctions were held. In addition, one can envisage that speculators and investors will be buying permits at the auctions in order to sell them on the secondary market. Thus, the effects of auctions on the performance of the secondary market are not as clear-cut as is often assumed.

7. Conclusions

Based on the policy framework and theoretical as well as experimental findings in the literature, an ascending clock auction format with the following characteristics was proposed by the authors and later proposed by the Australian government in their White Paper (Commonwealth of Australia 2008):

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

A remaining challenge with respect to the proposed design lies in the complexity of bidding in multi-clock auctions. Given the trade-off between complexity and efficiency when running simultaneous clock auctions and the limited experience with this particular auction approach, laboratory experiments should be performed prior to conducting the auction(s). They would not only help to identify potential problems with the design but could also serve to test the exact rules for the auction software.

Finally, the Australian auction proposal is unique in providing all of these different options and functions (e.g. double-sided, proxy bidding). If it proves to be feasible and efficient, it may be used as a prototype for other countries introducing emissions trading schemes.

References

Armstrong, M. (2000). Optimal multi-object auctions, *Review of Economic Studies* 67, 455–481.

Australian Government (2009). *Carbon Pollution Reduction Scheme Bill 2009, 09199b02*. Available from URL: http://parlinfo.aph.gov.au [accessed 5 December 2009].

Ausubel, L.M. (1999). A generalized Vickrey auction, Working Paper, University of Maryland.

Ausubel, L.M. (2006). An efficient dynamic auction for heterogeneous commodities, *American Economic Review* 96(3), 602–629.

Ausubel, L.M. and Cramton, P. (2002). Demand reduction and inefficiency in multi-unit auctions, Working Paper, University of Maryland.

Ausubel, L.M. and Cramton, P. (2004). Auctioning many divisible goods, *Journal of the European Economic Association* 2, 480–493.

Ausubel, L.M., Cramton, P., Filiz-Ozbay, E., Higgins, N., Ozbay, E. and Stocking, A. (2009). Common value auctions with liquidity needs: an experimental test of a troubled assets reverse auction, Working Paper, University of Maryland.

Ballard, C.L., Shoven, J.B. and Whally, J. (1985). General equilibrium computations of the marginal welfare costs of taxes in the United States, *American Economic Review* 75, 128–138.

Benz, E. and Ehrhart, K.-M. (2007). Which allocation rule generates true price signals for the CO_2 allowance market? Proceedings of the 2007 ECEEE Summer Study – Saving energy – Just Do It!; 4–9 June 2007, Colle sur Loup, France, pp. 125–134.

Betz, R. and Neuhoff, K. (2008). The use of auction revenues to avoid negative impact on poor households, in Neuhoff, K. and Matthes, F. (eds), *The Role of Auctions for Emissions Trading*. Climate Strategies Report, Cambridge, pp. 66–69.

Betz, R., Rogge, K. and Schleich, J. (2006). EU emissions trading: an early analysis of national allocation plans for 2008–2012, *Climate Policy* 6(4), 361–394.

Cason, T.N. and Plott, C.R. (1996). EPA's new emissions trading mechanism: a laboratory evaluation, *Journal of Environmental Economics and Management* 30, 133–160.

CEC (2003). *Directive 2003/87/EC of the European Parliament and of the Council for Establishing a Scheme for Greenhouse Gas Emission Allowance Trading within the Community and Amending Council Directive 96/61/EC*. CEC, Brussels.

CEC (2009). *Directive 2009/29/EC of the European Parliament and of the Council Amending Directive 2003/87/EC so as to Improve and Extend the Greenhouse Gas Emission Allowance Trading Scheme*, 23 April 2009. CEC, Brussels.

Commonwealth of Australia (2008). *Carbon Pollution Reduction Scheme: Policy White Paper*. Commonwealth of Australia, Canberra.

Cook, G., Solsbery, L., Cramton, P. and Ausubel, L.M. (2005). *EU Emissions Trading Scheme, Planning for Auction or Sale*, Report prepared on behalf of the Environmental Resources Management Consultancy for the UK Department of Trade and Industry.

Cramton, P. (1997). The FCC spectrum auctions: an early assessment, *Journal of Economics & Management Strategy* 6(3), 431–495.

Cramton, P. and Kerr, S. (2002). Tradeable carbon permit auctions: how and why to auction not grandfather, *Energy Policy* 30, 333–345.

Cramton, P., Shoham, Y. and Steinberg, R. (eds) (2006). *Combinatorial Auctions*. MIT Press, Cambridge, MA.

Dales, J.H. (1968). *Pollution, Property & Prices*. University of Toronto Press, Toronto.

Deutscher Bundestag (2007). *Gesetz zur Änderung der Rechtsgrundlagen zum Emissionshandel im Hinblick auf die Zuteilungsperiode 2008 bis 2012*, Bundesgesetzblatt Jahrgang 2007 Teil I Nr. 38, Berlin, 10. August 2007, pp. 1788–1808.

Deutsches Verbändeforum (2005). *Künstliche Verteuerung des Strompreises durch Missbrauch des CO_2-Zertifikathandels/Umweltminister Trittin soll für Aufklärung sorgen*, press release 21 July 2005: in "Verbandspresse". Available from URL: http://www.verbaende.com/News.php4?m = 32126 [accessed 5 August 2005].

Diekmann, J. and Schleich, J. (2006). Auktionierung von Emissionsrechten – Eine Chance für mehr Gerechtigkeit und Effizienz im Emissionshandel, *Zeitschrift für Energiewirtschaft* 30(a), 259–266.

Engelbrecht-Wiggans, R. and Kahn, C.M. (1998). Multi-unit auctions with uniform prices, *Economic Theory* 12, 227–258.

Evans and Peck (2007). *Possible Design for a Greenhouse Gas Emissions Trading System: Further definition of the auction proposals in the NETT Discussion Paper*. July 2007, Sydney. Available from URL: http://www.ceem.unsw.edu.au/content/userDocs/Auction_Design_Report.pdf [accessed 5 December 2007].

Fazekas, F. (2008). *Auction Design, Implementation and Results of the European Union Emissions Trading Scheme*. Available from URL: http://www.aprec.net/documents/08-04-28_eu_ets_auctions_fazekas.pdf [accessed 5 May 2009].

Feldstein, M. (1999). Tax avoidance and the deadweight loss of the income tax, *Review of Economics and Statistics* 81, 674–680.

Goulder, L.H. (1995). Environmental taxation and the 'double dividend': a reader's guide, *International Tax Public Finance* 2, 157–183.

Hahn, R. (2009). Greenhouse gas auctions and taxes: some political economy considerations, *Review of Environmental Economics and Policy* 3, 167–188.

Holt, C., Shobe, W., Burtraw, D., Palmer, K. and Goeree, J. (2007). *Auction Design for Selling CO_2 Emission Allowances under the Regional Greenhouse Gas Initiative, Final Report*. Available from URL: http://www.rggi.org/docs/rggi_auction_final.pdf [accessed January 2008].

Jotzo, F. and Betz, R. (2009). Linking the Australian emissions trading scheme, *Climate Policy* 9, 402–414.

Manelli, A.M., Sefton, M. and Wilner, B. (2006). Multi-unit auctions: a comparison of static and dynamic mechanisms, *Journal of Economic Behavior & Organization* 61, 304–323.

Montero, J.P. and Ellermann, A.D. (1998). Explaining low sulphur dioxide allowance prices: the effect of expectation errors and irreversibility, Working Paper No. 98011, Massachusetts Institute of Technology, Center for Energy and Environmental Policy Research. Available from URL: http://web.mit.edu/ceepr/www/publications/workingpapers/98011.pdf [accessed 19 May 2007].

Montgomery, W. (1972). Markets in licenses and efficient pollution control programs, *Journal of Economic Theory* 5, 395–418.

Neuhoff, K. (2007). Auctions for CO_2 allowances – a straw man, Paper prepared from the workshop on Auctions for CO_2 Allowances, held at Cambridge University. Available from URL: http://www.electricitypolicy.org.uk/TSEC/2/prog1.html [accessed 16 March 2007].

Porter, D., Rassenti, S., Shobe, W., Smith, V. and Winn, A. (2009). The design, testing and implementation of Virginia's NOx allowance auction, *Journal of Economic Behavior & Organization* 69(2), 190–200.

Regional Greenhouse Gas Initiative (2008). *Regional Greenhouse Gas Initiative Model rule, 12/31/08 final with corrections*. Available from URL: http://www.rggi.org/docs/Model%20Rule%20Revised%2012.31.08.pdf [accessed 5 January 2009].

Sijm, J., Neuhoff, K. and Chen, Y. (2006). CO_2 cost pass through and windfall profits in the power sector, *Climate Policy* 6, 49–72.

Vickrey, W. (1961). Counterspeculation, auctions, and competitive sealed tenders, *Journal of Finance* 16(1), 8–37.