Britain's Electricity Capacity Auctions: Lessons from Colombia and New England

The jury is still out on the need for government-organized capacity markets in order to achieve efficient long-run investments in electricity generation. When new capacity markets are introduced, however, it is important that they are well designed and take account of existing experience and previous design failures. Experience in both Colombia and New England provide a stark warning about the dangers of placing descending clock auctions at the center of electricity capacity markets. Among alternative auction design options, a sealed-bid auction is a better choice.

David Harbord and Marco Pagnozzi

David Harbord *is Director of Market Analysis Ltd., an Oxford, UK-based economics consultancy. He has published numerous articles analyzing the performance of the British electricity wholesale, contract, and capacity investment markets. His widely cited 1993* Economic Journal *paper was the first to directly apply insights from auction theory to the study of decentralized electricity markets. His academic research focuses on the design and performance of electricity auctions; collusive access pricing agreements; the extra-legal governance of trade agreements; and the welfare economics of alternative approaches to regulating access charges in mobile networks. He has advised regulatory authorities and energy companies in the UK, Europe, Australia, Brazil, and Colombia and has acted as an economic adviser to the majority of telecommunications and media companies in the UK in regulatory proceedings and competition policy litigation.*

Marco Pagnozzi *is Associate Professor of Economics at the University of Naples Federico II and a member of the Centre for Studies in Economics and Finance (CSEF). His research areas are in auction theory and industrial organization and he has published numerous scientific papers in academic journals. He has advised widely on bidding strategies in spectrum auctions and takeover contests, and he has been consulted by governments in several countries on the design of auctions for spectrum licenses, privatizations, electricity markets, natural gas, greenhouse gas emission allowances, bank services, medical services, and export licenses. He has also worked extensively on combinatorial auctions for radio spectrum in Europe and on firm energy capacity auctions and auctions for long-term natural gas contracts in Colombia.*

The authors thank David Robinson and Malcolm Keay (Oxford Institute for Energy Studies), Dan Harris and Kathleen Spees (The Brattle Group) and Stephen Littlechild (Judge Business School) for helpful comments and suggestions that improved the article.

I. Introduction

In the past decade, electricity capacity markets have been introduced in New England, the PJM, Western Australia, and Colombia, and are currently being considered in Germany, Texas, Italy, and Peru. In the UK, the Department of Energy and Climate Change (DECC) has recently confirmed a design for Britain's first electricity generation capacity auction to be held in December 2014 for delivery of new capacity in 2018.[1] Further auctions will be held in 2017 and subsequent years. The purpose of these auctions is to ensure that there will always be sufficient

 1040-6190/ http://dx.doi.org/10.1016/j.tej.2014.05.004

generation capacity available to meet peak demands for electricity, and energy companies will receive an auction-determined capacity fee in return for an obligation to deliver energy in periods of system stress, when capacity margins are tight.

In theory, electricity capacity auctions work in tandem with electricity spot and forward markets to ensure that energy companies invest in sufficient capacity to meet consumer demand for reliability. But economists disagree about whether electricity markets – unlike the markets for breakfast cereals or new cars – require special institutions like government-organized capacity markets to achieve efficient long-run investments. Those in favor point to ''market failures'' such as the lack of demand-side participation in many electricity markets which makes market clearing problematic in times of scarcity, or to ''missing money'' due to regulatory caps on peak-period prices, to justify the need for intervention. Excessive price volatility and coordination failures are further factors that have been adduced in support of introducing capacity markets.[2]

Other economists argue that there is nothing special about electricity, and point to the numerous examples of liberalized electricity markets that perform well without such measures. They also point out that rather than reflecting consumer preferences for reliability, in reality capacity markets procure generation resources to satisfy government-mandated levels of supply security, based on estimates of future demand which often turn out to be wildly incorrect.[3]

Some analysts argue that existing capacity markets have failed to achieve their intended purpose of ensuring a reliable supply of electricity, despite the high costs they have imposed on consumers.[4]

Some analysts argue that existing capacity markets have failed to achieve their intended purpose of ensuring a reliable supply of electricity.

Whatever the theoretical pros and cons, policymakers in many countries are now expressing concerns that liberalized energy markets might not guarantee reliable long-run supplies of electricity, and the UK government obviously does not believe that the current energy market will deliver enough new power stations to keep the lights on in the future. We will not enter into this debate in this article. Rather, given that a capacity market is being introduced in Britain, we ask whether the auction design currently being proposed by the DECC is fit for its intended purpose. The DECC's capacity auction is virtually identical to the auction introduced first in the New England ISO's capacity market in 2006, and later for Colombia's ''Firm Energy'' market in 2008.[5] Experience to date with this auction design has been mixed at best.

II. The DECC's Auction Design

The DECC proposes to use periodic descending, uniform-price clock auctions to elicit offers to supply new capacity from generating companies to meet predicted demand in future years. In a descending clock auction the auctioneer initially announces a high price for new capacity so that total supply exceeds demand.[6] Price is then progressively reduced until enough capacity offers are withdrawn so that excess supply is eliminated.[7] The minimum price for which there is still sufficient capacity offered to meet demand sets the capacity fee to be paid to all successful suppliers in the auction, including existing resources. New capacity offered in the auctions will be able to sign 15-year capacity agreements at the auction clearing price. Existing capacity will have access to rolling one-year agreements at auction-determined prices.

The argument in favor of using a clock auction is that it allows for what economists call ''price

1040-6190/ http://dx.doi.org/10.1016/j.tej.2014.05.004

discovery.'' The idea is that generating companies face significant ''common value'' uncertainty concerning the value of a new power plant and this uncertainty will lead them to bid conservatively, i.e. by demanding a higher price for new capacity, to avoid falling victim to the ''winner's curse.'' Significant levels of common value uncertainty could even induce generating companies not to participate in the auction, if they are not prepared to face the value risk of constructing a new power plant.[8]

A clock auction alleviates this problem by allowing bidders to observe the changing balance of demand and supply during the auction, and to revise their value estimates in light of this information. This reduction of uncertainty enables bidders to bid more aggressively without fear of the winner's curse, because capacity offers can be reduced when a bidder sees a significant number of other offers withdrawn from the auction. This can both reduce costs and improve efficiency. The DECC recognizes that there may be an increased risk of collusion in a descending clock auction, as compared to a sealed-bid auction, because bidders can observe and respond to their competitors' behavior round by round. It nevertheless argues that this consideration is outweighed by the potential for improved efficiency. As the DECC puts it, ''*the ability to observe the behaviour of participants in previous rounds in a descending clock auction, and to adapt bidding behaviour on this basis, mitigates risk and should increase the likelihood that the most efficient providers win capacity agreements*.''[9]

Price discovery is only relevant, however, if the products in the auction have common value elements, and if bidders have private information about these values. While the DECC suggests that common value uncertainty and price discovery have been key considerations in its decision to adopt the descending clock auction format, there are reasons for doubting that these are compelling concerns in electricity capacity markets. For generators participating in a capacity auction, the main source of common value uncertainty is the future path of electricity prices, which determines the revenues they will receive from selling electricity into spot or forward markets. But it is far from clear that generators have any useful information to ''share'' about this in a descending clock auction: no generation company is likely to have better, or even different, information on the future path of electricity prices than any other. Investment costs, on the other hand, do not exhibit true common value uncertainty. To the extent that there is uncertainty about them, it concerns idiosyncratic and private components of companies' costs. Hence energy companies are unlikely to reevaluate their capacity cost estimates in light of information revealed in an auction.[10] In any event, since participants do not know the identities of other bidders active in the clock auction, it is not clear what information about investment costs they could possibly infer solely from observing the level of excess supply in each round of the auction.[11]

Significant levels of common value uncertainty could even induce generating companies not to participate in the auction.

III. Experience in Colombia and New England

Whatever one believes about the desirability of price discovery in electricity capacity auctions, experience from using the clock auction format in Colombia has demonstrated that a much more pressing concern is the opportunity it provides large bidders to strategically manipulate auction prices by allowing them to see exactly when the withdrawal of a capacity offer will end the auction at an artificially high price. In

  http://dx.doi.org/10.1016/j.tej.2014.05.004

other words, providing information on the balance of supply and demand during each round of the auction allows bidders to see the precise point at which they become ''pivotal,'' and able to unilaterally induce a high auction price by strategically adjusting their bidding behavior. This supply reduction problem is especially acute when a relatively small number of large energy companies dominate the markets for new generation capacity, as is the case in both Colombia and Britain, and when bids are for discrete capacity units. Moreover, the presence of large bidders with significant amounts of existing capacity in the auction that will receive the auction-clearing price set by new capacity, further exacerbates the market power problem.

The Colombian Commission for the Regulation of Energy and Gas (CREG) has now held two capacity auctions using the descending clock auction format: the first in May 2008 and the second in December 2011. The 2008 auction ended early at the first point at which a large bidder could see that it had become ''pivotal'' and able to withdraw one of its offers to set a high capacity price. To avoid this happening again, in 2011 the CREG adopted measures to make this strategy harder by reducing the amount of information on demand and supply revealed to bidders during the auction. This was not sufficient, however, and the auctioneers abandoned the auction after the initial two rounds and effectively held a sealed-bid auction in its place.[12] They subsequently recommended changing the auction format to a combinatorial clock auction followed by a sealed-bid stage to reduce the risk of this being repeated in the future.[13]

We know less about the New England experience, but it also suggests problems. The first seven auctions from 2007 to 2013 concluded at the auction floor price of $3.15/kW-month with a significant excess supply. Given the large amounts of excess capacity and the artificial price floors, the outcomes of these auctions provide little information about their performance. Prior to the 2014 auction, however, the price floor was abolished and significant amounts of generation capacity were withdrawn from the market. The eighth auction thus commenced at a starting price of $15.82/kW-month and concluded after a single round at a clearing price of $15.00/kW-month, when a generator withdrew its capacity from the auction.[14] This suggests an outcome comparable to the Colombian experience in which a single pivotal bidder was able to withdraw capacity to set a high price early in the auction.

Experience in both Colombia and New England provides a stark warning about the dangers of placing descending clock auctions at the center of electricity capacity markets.

Unlike the DECC's proposal to pay both new and existing capacity the auction clearing price, however, under the New England rules only 1.370 MW of new resources will receive the $15 price. Existing resources (with the exception of the constrained region around Boston) will be paid a $7.025/kW-month price ceiling. Decoupling the prices paid to new versus existing capacity is a potentially important market power mitigation measure, especially when most of the new capacity offered in the auction is likely to come from a relatively small number of energy companies which already own the lion's share of extant capacity.

IV. Auction Design Choices

Experience in both Colombia and New England provides a stark warning about the dangers of placing descending clock auctions at the center of electricity capacity markets. The problems experienced in Colombia are endemic to descending clock auctions for generation with large, indivisible capacity bids so similar problems will likely arise in the UK, particularly since in both markets generation is

 1040-6190/ http://dx.doi.org/10.1016/j.tej.2014.05.004

dominated by a handful of large companies. While not identical to Colombia's, New England's experience raises further questions about the efficacy of the DECC's current auction design.

In our second report for the Colombian Commission for the Regulation of Energy and Gas we considered three possible options for addressing these market power issues:

- an increase in the amount of demand uncertainty faced by bidders in the auction;
- the use of a combinatorial clock auction; or
- adoption of a sealed-bid uniform-price or discriminatory-price auction.

We discuss each of these options briefly in turn.

A. Increased demand uncertainty

Demand uncertainty can be increased either by introducing a random component in demand, so that reported information on excess supply is sufficiently uncertain to make price manipulation strategies more risky, or by allowing the auctioneer to reduce demand after observing the bids submitted in any round.[15] It is important to recall, however, that the primary rationale for using a descending clock auction is price discovery, and as we reduce the amount of information provided during the auction, or increase uncertainty about it, we are reducing the opportunities for learning being provided to bidders. Hence significant reductions in the information provided, or introducing significant degrees of uncertainty, violate the spirit of the entire enterprise. It thus makes little sense to address the problem of pivotal bidders in clock auctions by progressively increasing demand uncertainty parameters, or reducing opportunities for price discovery in other ways.

Significant reductions in the information provided, or introducing significant degrees of uncertainty, violate the spirit of the entire enterprise.

B. Combinatorial clock auction

Combinatorial clock auctions are used to sell radio spectrum to telecommunications companies in a number of countries. They are dynamic auctions that allow bidders to bid on packages of objects.[16] The auction begins with a ''clock'' stage in which prices increase for objects with excess demand, until there is no excess demand for any object. This is followed by a sealed-bid round, in which bidders can increase their bids on packages on which they have previously bid and submit new bids on other packages.[17] All of the bids are then used to determine the value-maximizing assignment of objects on sale. It is an appropriate design for auctions in which bidders have heterogeneous, but similar objects to sell and there are complementarities between them, as it allows bidders to avoid the ''exposure'' problem.[18]

Electricity capacity or firm energy auctions are for a single, potentially divisible, product – generation capacity in GWh – hence in this case it is unlikely that a combinatorial auction would result in any significant improvements in efficiency. A combinatorial auction could in principle be useful where bidders have decreasing marginal costs of production from a single generating plant, so are willing to sell larger quantities at a lower per unit price than a smaller quantity. But combinatorial auctions introduce a number of additional complications. For example, a particular and typically complex pricing rule must be chosen. The ''second-price'' rule adopted in a number of combinatorial spectrum auctions has some undesirable properties. It may lead to larger companies being paid higher prices than smaller ones for identical quantities of energy, and it makes it very difficult for bidders to anticipate how their bids will affect the final auction prices, which may make them unwilling to bid truthfully.

  http://dx.doi.org/10.1016/j.tej.2014.05.004

Moreover, an activity rule must be designed for the clock stage of the auction, and there is no agreement to date over the most appropriate one.[19]

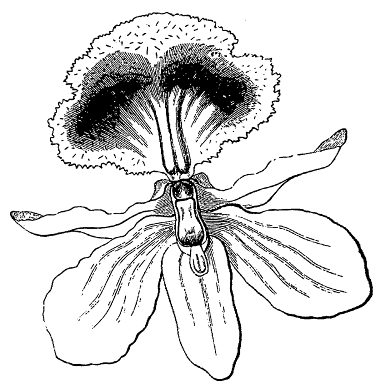
Hence, the additional cost in complexity created by a combinatorial auction, both in terms of implementation by the auctioneer and choice of bidding strategies by participants, likely outweighs any advantages in resolving issues to do with economies of scale or cost complementarities.

C. Sealed-bid uniform-price or discriminatory-price auction

Since price discovery does not seem to play any significant role from the point of view of the bidders in capacity auctions, a sealed-bid auction appears to be the best solution. In this auction format bidders submit sealed bids that represent their supply functions – i.e. the lowest prices at which they are willing to sell different quantities of capacity – and the quantity acquired by the auctioneer equates bidders' total supply to the auctioneer's demand.

The two most commonly used multi-object sealed-bid auctions for a homogeneous divisible good such as generation capacity are the uniform-price (''pay-as-clear'') and the discriminatory-price (''pay-as-bid'') auction. In a uniform-price auction all capacity is sold by winning bidders at the same market-clearing price, while in a discriminatory-price auction each winning bidder is paid its own bid for the quantities that it sells.

Arguably, the main advantage of a uniform-price auction is that it satisfies the ''law of one price.'' Since all capacity is sold at the same price, no bidder is paid more than any other for an identical good. This makes



bidding particularly straightforward for small bidders who can simply bid their own valuations and receive the auction determined market-clearing price. In a discriminatory-price auction, on the other hand, winners are paid their own bids so need to have good information about the distribution of their rivals' valuations in order to determine an optimal bidding strategy. Hence bidding in these auctions can be especially complex for small bidders.

A potential disadvantage of uniform-price auctions is that they may have multiple Nash equilibria, in some of which bidders implicitly coordinate on high prices, by offering extremely low prices for quantities smaller than their equilibrium share.[20] These high-price equilibria exist when the quantity demanded by the auctioneer is fixed and bidders can submit continuous supply functions. However, the auctioneer can reduce them by demanding a random quantity, or it can eliminate them altogether by maintaining the flexibility to adjust its demand after receiving bidders' bids.[21] Moreover, high-price equilibria do not arise if bids are discrete, as in almost all actual auctions, and the quantity demanded is random or uncertain.[22]

In discriminatory auctions coordinated supply reduction resulting in high-price equilibria is less of a problem because each bidder receives its actual bid for the quantity that it sells.[23] This is probably the main advantage of a discriminatory-price auction compared to a uniform-price auction.

The academic literature on discriminatory-price and uniform-price auctions finds neither auction format for sealed-bid multi-object auctions to be unambiguously superior to the other.[24] The empirical evidence is also inconclusive. On balance, the advantages of a uniform-price auction in terms of price uniqueness and simplicity for small bidders probably makes it a preferable choice over a discriminatory-price auction, especially since uncertainty about competitors' strategies and the

http://dx.doi.org/10.1016/j.tej.2014.05.004

actual market-clearing price generated by a sealed-bid auction will likely be sufficient to discourage bidders from strategically manipulating their bids.

D. Choice of price in a uniform-price auction

A final issue is the choice of price in a uniform-price auction. With discrete bids or supply functions, there is some flexibility in the definition of a market-clearing price: any price between the highest winning (or accepted) bid and the lowest losing (or rejected) bid can equate demand and supply. Moreover, because of the indivisibility of bids these auctions will generically terminate with either excess supply or excess demand.

In a sealed-bid auction, setting price equal to the highest accepted bid may increase bidders' incentive to strategically reduce supply. The incentive to unilaterally reduce supply stems from the fact that, if a bid is pivotal, it affects the price paid to all capacity accepted in the auction, so bidders have an incentive to increase their bids even though this may reduce the quantity they sell.[25] By contrast, if the auction price is set equal to the lowest rejected bid, increasing a bid will increase the auction price only if this bid is rejected. Hence, a bidder may increase the price it is paid for its other winning plants only by increasing its bid for a losing plant; but a bid for a specific plant or unit will never affect the price paid for the energy produced by that plant. Therefore, bidders will perceive a lower incentive to reduce supply in a uniform-price auction when the auction price is equal to the lowest rejected bid.

Choosing a market-clearing price equal to the lowest rejected bid may appear to be the

preferable option. However, for any given set of bids, an auction price equal to the lowest rejected bid increases the price paid by the auctioneer for all of the capacity that it purchases, and nothing guarantees that this price differential will be small.[26]

V. Conclusion

The jury is still out on the need for government-organized capacity markets in order to achieve efficient long-run investments in electricity generation. When new capacity markets are introduced however, it is important that they be well designed and take account of existing experience and previous design failures. Experience in both Colombia and New England provide a stark warning about the dangers of placing descending clock auctions at the center of electricity capacity markets. The problems experienced in Colombia are endemic to descending clock auctions for generation with large, indivisible capacity bids so similar problems will likely arise in the UK, particularly since in both markets generation is dominated by a handful of large companies. While not identical to Colombia's, New England's experience raises further questions about the efficacy of the DECC's current auction design.

Somewhat paradoxically, the Department of Energy & Climate Change is simultaneously proposing to use either a discriminatory or uniform price sealed-bid auction to allocate contracts for differences to renewable, low-carbon energy projects,[27] despite the fact that the case for a descending clock auction is arguably much stronger for these newer technologies.[28] A sealed-bid auction format should be considered for the technology-neutral capacity market as well.

While there are a number of design options for multi-unit sealed-bid auctions, uniform price auctions have the advantage of making bidding simple, thus encouraging the entry of smaller bidders into the market. It is less clear whether the uniform price

  http://dx.doi.org/10.1016/j.tej.2014.05.004

should be set by the highest accepted or the lowest rejected bid. Regulatory authorities, however, find it notoriously difficult to explain why an auction should pay higher prices to winning bidders than seems strictly necessary, especially when these differences can be large.■

Endnotes:

1. Department of Energy & Climate Change, 2013, June. Electricity Market Reform: Capacity Market – Detailed Design Proposals; Department of Energy & Climate Change, 2013, October. Electricity Market Reform: Capacity Market – Update.

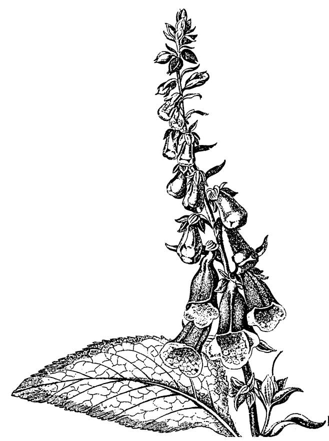
2. Cramton, P., Ockenfels, A., 2012. Economics and design of capacity markets for the power sector. Z. Energie., 36, 113–134; Cramton, P., Ockenfels, A., Stoft, S., 2013, September. Capacity market fundamentals. Econ. Energy Environ. Policy, 2, 2; Joskow, P., 2008. Capacity payments in imperfect electricity markets: need and design. Utilities Policy, 16, 159–170.

3. Wolak, F., 2004. What's Wrong with Capacity Markets? Stanford University; Wolak, F., 2013. Economic and political constraints on the demand-side of electricity industry re-structuring processes. Rev. Econ. Inst., 4 (Winter (1)); Kleit, A., Michaels, R., 2013. If you buy the power, why pay for the power plant? Reforming Texas electricity markets. Regulation 36 (Summer), 2.

4. For example, American Public Power Association, 2013, February. RTO Capacity Markets and Their Impacts on Consumers and Public Power, Fact Sheet; Nelder, C., 2013, September. The Perils of Electricity Capacity Markets. Green Tech Media.

5. See Cramton, P., Stoft, S., 2005, August/September. A capacity market that makes sense. Electricity J., 18, 43–54; Cramton, P., Stoft, S., 2007. Colombia's firm energy market. In: Proceedings of the Hawaii International Conference on System Sciences.

6. The DECC proposes to set the starting price in the first auction at a multiple of the cost of a new build open cycle gas turbine (OCGT) plant minus expected electricity market revenue. This is currently estimated to be £75/kW. Department of Energy & Climate Change, 2013, October. Electricity Market Reform: Consultation on Proposals for Implementation.



7. Because the offers in these auctions are for discrete capacity units, the auction may end with some excess supply as it is not always possible to match demand and supply exactly at any price.

8. A ''common value'' asset is one that all buyers or sellers would value equally if they shared all of the relevant information to estimate the asset's value. Financial assets are one example, and oil fields are also frequently cited. The ''winner's curse'' refers to the phenomenon whereby winning in an auction can be bad news for the winning bidder because – by the very fact of winning – she learns that all of the losing buyers (or sellers) had lower (or higher) estimates of this common value. So it is likely that her estimate of the common value was overly optimistic. Understanding this in advance, it is optimal to bid more conservatively in a common value auction (than in a private value one) to avoid winning at a price which is unprofitable. See Bulow, J., Klemperer, P., 2002. Prices and the winner's curse. RAND J. Econ.; Wilson, R., 1969. Competitive bidding with disparate information. Manage. Sci., 13 (11), 816–820; Capen, E., Clapp, R., Campbell, W. Competitive bidding in high-risk situations. J. Petrol. Technol., 23 (6), 641–653.

9. Department of Energy & Climate Change, 2013, June. Electricity Market Reform: Capacity Market – Detailed Design Proposals, p. 26.

10. For a more detailed discussion of these issues see Harbord, D., Pagnozzi, M., 2008, November 25. Review of Colombian Auctions for Firm Energy, report for the Colombian Commission for the Regulation of Energy and Gas. In our conversations with auction participants in Colombia, all reported that their reserve prices did not (and would not) change during the auction and that ''learning'' was not an issue for them.

11. Cramton, P., Stoft, S. *supra* note 5 recommended reporting supply by resource type at the close of each round. This recommendation has never been adopted for capacity auctions, however.

12. Harbord, D., Pagnozzi, M., 2012, December 18. The Colombian experience is detailed in our report ''Second Review of Firm Energy Auctions in Colombia'', for the Colombian Commission for the Regulation of Energy and Gas.

13. Dinkin, S., Cramton, P., 2012, January 5. Subasta para la Asignación de Obligaciones de Energía Firme: Auctioneer's Report. Full Spectrum Auctions Inc.

14. Peak Oil News, 2014, February 18. Big numbers for New England Electricity auction might not be enough to bring new capacity; Business Wire, 2014, February 5. Auction Ends with Slight Shortfall in Power System Resources Needed for 2017–2018 in New England. For the New England ISO's official auction results, see ''Forward

 http://dx.doi.org/10.1016/j.tej.2014.05.004

Capacity Market (FCA 8) Result Report, February 7, 2014.''

15. See McAdams, D., 2007. Adjustable supply in uniform price auctions: non-commitment as a strategic tool. Econ. Lett., 95 (1), 48–53.

16. Ausubel, L., Cramton, P., Milgrom, P., 2006. The clock-proxy auction: a practical combinatorial auction design. In: Cramton, Shoham, Steinberg (Eds.), Combinatorial Auctions. MIT Press, pp. 115–138 (Chapter 5); Ausubel, L., Milgrom, P., 2002. Ascending auctions with package bidding. Front. Theor. Econ., 1 (1).

17. See Cramton, P., 2013. Spectrum auction design. Rev. Ind. Organ., 42 (2), 161–190, for a more detailed discussion of this auction design.

18. The exposure problem refers to the risk that, with complementarities in valuations, bidders win some, but not all, of the objects they want, and hence pay a price that is higher than their valuation for the objects that they actually win.

19. Ausubel, L., Cramton, P., 2011. Activity Rules for the Combinatorial Clock Auction (Working Paper). University of Maryland.

20. Wilson, R., 1979. Auctions of shares. Q. J. Econ., 93, 675–689.

21. Klemperer, P., Meyer, M., 1989. Supply function equilibria in oligopoly under uncertainty. Econometrica, 58 (1), 15–41; McAdams, D., *supra* note 15.

22. Kremer, I., Nyborg, K., 2004. Divisible good auctions: the role of allocation rules. RAND J. Econ., 35 (1).

23. Back, K., Zender, J., 1993. Auctions of divisible goods. Rev. Financ. Stud., 6, 733–764.

24. Fabra, N., von der Fehr, N.-H., Harbord, D., 2006. Designing electricity auctions. RAND J. Econ. 37 (1), 23–46.

25. With indivisible bids, this problem is exacerbated by the fact that the marginal winning bid can sometimes be increased without affecting the quantity sold by the marginal winning plant. See Harbord, D., Pagnozzi, M., *supra* note 12 for a discussion of this issue.

26. See Department of Energy & Climate Change, 2013, October. Electricity Market Reform – Capacity Market Update. Annex A for a discussion. We might have also considered multi-unit Vickrey auctions for capacity, but these are significantly more complex, do not result in a uniform price, and face other well-known difficulties. See Fabra, N., von der Fehr, N.-H., Harbord, D., 2002. Modeling electricity auctions. Electricity J., 15 (7), 72–81.

27. Department of Energy & Climate Change, 2014, January 16. Electricity Market Reform: Allocation of Contracts for Difference – Consultation on Competitive Allocation.

28. See Policy Exchange, 2013, December 16. Going, Going, Gone: The role of Auctions and Competition in Renewable Electricity Support.

A sealed-bid auction format should be considered for the technology-neutral capacity market as well.

 1040-6190/, http://dx.doi.org/10.1016/j.tej.2014.05.004