The Product-Mix Auction: a New Auction Design for Differentiated Goods

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Abstract

I describe a new static (sealed-bid) auction for differentiated goods—the "Product-Mix Auction". Bidders bid on multiple assets simultaneously, and bid-takers choose supply functions across assets. The auction yields greater efficiency, revenue, information, and trade than running multiple separate auctions. It is also often simpler to use and understand, and less vulnerable to collusion, than a simultaneous multiple round auction. I designed it after the 2007 Northern Rock bank-run to help the Bank of England fight the credit crunch; in 2008 the U.S. Treasury planned using a related design to buy "toxic assets"; it may be used to purchase electricity. (100 words)

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I have advised the Bank of England and the U.S. Treasury and have been consulted by other Central Banks, government agencies, etc., about these issues. I thank the relevant officials for help, but the views here are my own and do not represent those of any organisation. I am very grateful to Jeremy Bulow and Daniel Marszalec for their help in advising the Bank of England. I also particularly benefited from discussions with Elizabeth Baldwin and Marco Pagnozzi, and thank Olivier Armantier, Eric Budish, Vince Crawford, Aytek Erdil, Meg Meyer, Moritz Meyer-ter-Vehn, Rakesh Vohra, the editor and anonymous referees, and many other friends and colleagues for helpful advice.

1. Introduction

How should goods that both seller(s) and buyers view as imperfect substitutes be sold, especially when multi-round auctions are impractical?

This was the Bank of England's problem in autumn 2007 as the credit crunch began.[1] The Bank urgently wanted to supply liquidity to banks, and was therefore willing to accept a wider-than-usual range of collateral, but it wanted a correspondingly higher interest rate against any weaker collateral it took. A similar problem was the U.S. Treasury's autumn 2008 Troubled Asset Recovery Program (TARP) plan to spend up to $700 billion buying "toxic assets" from among 25,000 closely-related but distinct sub-prime mortgage-backed securities.

Because financial markets move fast, in both cases it was highly desirable that any auction take place at a single instant. In a multi-stage auction bidders who had entered the highest bids early on might change their minds about wanting to be winners before the auction closed,[2] and the financial markets might themselves be influenced by the evolution of the auction, which magnifies the difficulties of bidding and invites manipulation.[3]

An equivalent problem is that of a firm choosing its "product mix": it can supply multiple varieties of a product (at different costs), but with a total capacity constraint, to customers with different preferences between those product varieties, and where transaction costs or other time pressures make multiple-round auctions infeasible.[4] The different varieties of a product could include different points of delivery, different warranties, or different restrictive covenants on use.

[1] The crisis began in early August 2007, and a bank run led to Northern Rock's collapse in mid-September. Immediately subsequently, the Bank of England first ran four very-unsuccessful auctions to supply additional liquidity to banks and then consulted me. I got valuable assistance from Jeremy Bulow and Daniel Marszalec.

[2] Some evidence is that most bids in standard Treasury auctions are made in the last few minutes, and a large fraction in the last few seconds. For a multi-round auction to have any merit, untopped bids cannot be withdrawn without incurring penalties.

[3] The Bank of England insisted on a single stage auction. Ausubel and Cramton (2008) argued a multi-stage auction was feasible for the U.S. Treasury.

[4] That is, the Bank of England can be thought of as a "firm" whose "product" is loans; the different "varieties" of loans correspond to the different collaterals they are made against, and their total supply

This paper outlines a solution to all these problems – the Product-Mix Auction. I first developed it for the Bank of England,[5] and later made a similar proposal to the U.S. Treasury (which would probably have used a related design if it had not abandoned its plans to buy toxic assets).[6] At the time of writing, another Central Bank is exploring my design, and a regulator is considering a proposal to use my Product-Mix Auction for selling two close-substitute "types" of electricity.

My design is straightforward in concept – each bidder can make one or more bids, and *each* bid contains a *set* of mutually exclusive offers. Each offer specifies a price (or, in the Bank of England's auction, an interest-rate) for a quantity of a specific "variety". The auctioneer looks at all the bids and then selects a price for each "variety". From each bid offered by each bidder, the auctioneer accepts (only) the offer that gives the bidder the greatest surplus at the selected prices, or no offer if all the offers would give the bidder negative surplus. All accepted offers for a variety pay the same (uniform) price for that variety.

The idea is that the menu of mutually-exclusive sets of offers allows each bidder to approximate a demand function, so bidders can, in effect, decide how much of each variety to buy *after* seeing the prices chosen. Meanwhile the auctioneer can look at demand *before* choosing the prices; allowing it to choose the prices ex-post creates no problem here, because it allocates each bidder precisely

may be constrained. The Bank's "customers" are its counterparties, and the "prices" they bid are interest rates.

[5] See note 1. The Bank has used some simple versions and, at the time of writing, is moving towards full implementation of my proposal. I do *not* give full details of the Bank's objectives and constraints here, and not all the issues I discuss are relevant to it.

[6] After I proposed my solution to the Bank of England, I learned that Paul Milgrom was independently pursuing related ideas. He and I therefore made a joint proposal to the U.S. Treasury, together with Jeremy Bulow and Jon Levin, in September-October 2008. Other consultants, too, proposed a static (sealed-bid) design, and the Treasury was planning to run a first set of sealed-bid auctions, each for a related group of assets, when it suddenly abandoned its plans to buy subprime assets (in November 2008). Note, however, Larry Ausubel and Peter Cramton (who played an important role in demonstrating the value of using auctions for TARP, see e.g., Ausubel et al. (2008)) had proposed running dynamic auctions, and the possibility of doing this at a later stage was still being explored.

Milgrom (2009) shows how to represent a wide range of bidders' preferences such that goods are substitutes, and shows a linear-programming approach yields integer allocations when demands and constraints are integer, but my proposal seems more straightforward and transparent in a context such as the Bank of England's.

what that bidder would have chosen for itself given those prices.[7] Importantly, offers for each variety provide a competitive discipline on the offers for the other varieties, because they are all being auctioned simultaneously.

Compare this with the "standard" approach of running a separate auction for each different “variety”. In this case, outcomes are erratic and inefficient, because the auctioneer has to choose how much of each variety to offer before learning bidders' preferences, and bidders have to guess how much to bid for in each auction without knowing what the price-differences between varieties will turn out to be; the wrong bidders may win, and those who do win may be inefficiently allocated across varieties. Furthermore, each individual auction is much more sensitive to market power, to manipulation, and to informational asymmetries, than if all offers compete directly with each other in a single auction. The auctioneer’s revenues are correspondingly generally lower.[8] All these problems also reduce the auctions’ value as a source of information. They may also reduce participation, which can create "second-round" feedback effects furthering magnifying the problems.[9]

Another common approach is to set fixed price supplements for “superior” varieties, and then auction all units as if they are otherwise homogenous. This can sometimes work well, but such an auction cannot take any account of the

[7] That is, it chooses prices like a Walrasian auctioneer who is equating bidders' demand with the bid-taker's supply in a decentralized process (in which the privately-held information needed to determine the allocation is directly revealed by the choices of those who hold it).
The result assumes the conditions for “truthful” bidding are satisfied – see below.

[8] Thus, for example, if the U.S. Treasury had simply predetermined the amount of each type of security to purchase, ignoring the information about demand for the large number of closely-related securities, competition would have been inadequate. There were perhaps 300 likely sellers, but the largest 10 held of the order of two-thirds of the total volume, and ownership of many individual securities was far more highly concentrated.

[9] The feedback effects by which low participation reduces liquidity, which further reduces participation and liquidity, etc., are much more important when there are multiple agents on both sides of the market -- see Klemperer (2008).

auctioneer's preferences about the proportions of different varieties transacted.[10] Furthermore, the auctioneer suffers from adverse selection.[11]

The question, of course, is whether my alternative approach can actually be implemented, and -- crucially -- whether it can be done in a way that is simple and robust, and easy for bidders to understand, so that they are happy to participate:

Section 2 shows how my Product-Mix Auction does this. Section 3 discusses extensions. In particular, it is easy to include multiple buyers and multiple sellers, and "swappers" who may be on either, or both, sides of the market. Section 4 observes that the Product-Mix Auction is essentially a "proxy" implementation of a "two-sided" simultaneous multiple-round auction (SMRA) -- but because my design is static, it is simpler and cheaper and less susceptible to collusion and other abuses of market power than is a standard dynamic SMRA. Section 5 concludes.

2. A Simple Two-Variety Example

The application this auction was originally designed for provides a simple illustration. A single seller, the Bank of England (henceforth "the Bank") auctioned just two "goods", namely a loan of funds secured against strong collateral, and a loan of funds secured against weak collateral. For simplicity I refer to the two goods as "strong" and "weak".[12] In this context, a per-unit price is an interest rate. The rules of the auction are as follows:

[10] Moreover, a Central Bank might not want to signal its view of appropriate price-differentials for different collaterals to the market in advance of the auction.

[11] If, for example, the U.S. Treasury had simply developed a "reference price" for each asset, the bidders would have sold it large quantities of the assets whose reference prices were set too high -- and mistakes would have been inevitable, since the government had so much less information than the sellers.

[12] We assume (as did the Bank) that there is no adverse selection problem regarding collateral. For the case in which bidders have private information regarding the value of the collateral they offer, see Manelli and Vincent (1995).

1. Each bidder can make any number of bids. *Each bid* specifies a *single* quantity and an offer of a per-unit price for *each* variety. The offers in each bid are mutually exclusive.

2. The auctioneer looks at all the bids and chooses a minimum "cut-off" price for each variety – I will describe later in this section how it uses the construction illustrated in Figures 1a, 1b, and 2 to determine these minimum prices uniquely, for any given set of bids, and given its own preferences.

3. The auctioneer accepts all offers that exceed the minimum price for the corresponding variety, *except* that it accepts at most one offer from each bid. If both price-offers in any bid exceed the minimum price for the corresponding variety, the auctioneer accepts the offer that maximizes the bidder's surplus, as measured by the offer's distance above the minimum price.[13]

4. All accepted offers pay the minimum price for the corresponding variety – that is, there is "uniform pricing" for each variety.[14]

Thus, for example, one bidder might make three separate bids: a bid for £375 million at {5.95% for (funds secured against) weak OR 5.7% for (funds secured against) strong}; a bid for an additional £500 million at {5.75% for weak OR 5.5% for strong}; and a bid for a further £300 million at {5.7% for weak OR 0% for strong}. Note that since offers at a price of zero are never selected, the last bid is equivalent to a traditional bid on only a single collateral.[15]

An example of the universe of all the bids submitted by all the bidders is illustrated in Figure 1a. The prices (i.e., interest rates) for weak and strong are plotted vertically and horizontally, respectively; each dot in the chart represents an "either/or" bid. The number by each dot is the quantity of the bid (in £millions). The three bids made by the bidder described above are the enlarged dots highlighted in bold.

[13] See notes 16 and 19 for how to break ties, and ration offers that equal the minimum price.
[14] Klemperer (2008) discusses alternative rules.
[15] A bidder can, of course, restrict each of its bids to a single variety. Note also that a bidder who wants to guarantee winning a fixed total quantity can do so by making a bid at an arbitrarily large price for its preferred variety, and at an appropriate discount from this price for the other variety.

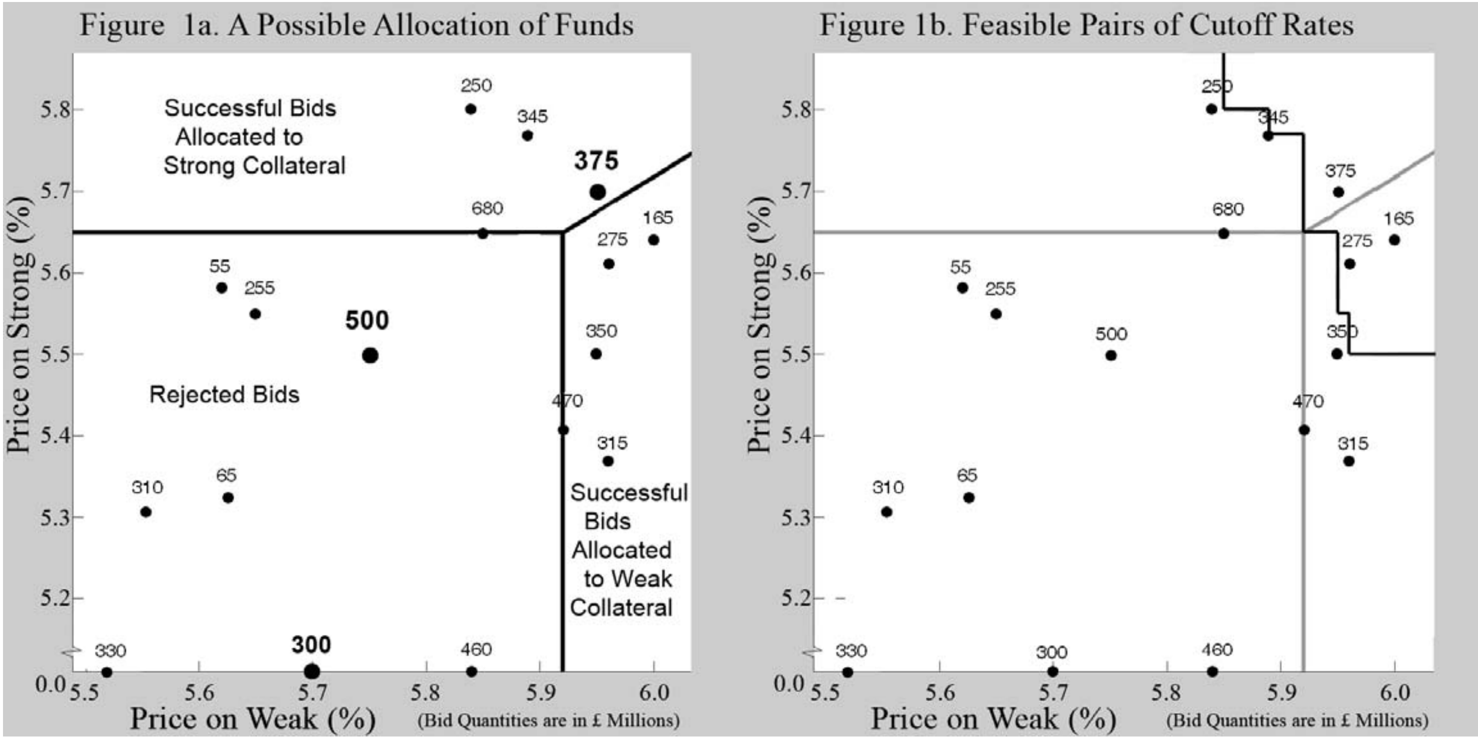

Figure 1: An example of bids in the Bank of England's auction.

The cut-off prices and the winning bids are determined by the Bank's objectives. If, for example, the Bank wants to lend £2.5 billion, and there are a total of £5.5 billion in bids, then it must choose £3 billion in bids to reject.

Any possible set of rejected bids must lie in a rectangle with a vertex at the origin. Figure 1a shows one possible rectangle of rejected bids, bounded by the vertical line at 5.92% and the horizontal line at 5.65%. If the Bank were to reject this rectangle of bids, then all the accepted bids -- those outside the rectangle -- would pay the cut-off prices given by the boundaries: 5.92% for weak, and 5.65% for strong.

Bids to the north-east of the rectangle (i.e, those which could be accepted for either variety) are allocated to the variety for which the price is further below the offer. So bids that are both north of the rectangle, and north-west of the diagonal 45° line drawn up from the upper-right corner of the rectangle, receive strong, and the other accepted bids receive weak.

Of course, there are many possible rectangles that contain the correct volume of bids to reject. On any 45° line on the plane, there is generally exactly one point that is the upper-right corner of such a rectangle.[16] It is easy to see that the set of all these points forms the stepped downward–sloping line shown in Figure 1b.[17] This stepped line is therefore the set of feasible pairs of cut-off prices that accept exactly the correct volume of bids.

Every point on Figure 1b's stepped line (i.e., every possible price pair) implies both a price-difference and (by summing the accepted bids below the corresponding 45° line) a proportion of sales that are weak. As the price-difference is increased, the proportion of weak sales decreases. Using this information we can construct the downward-sloping "demand curve" in Figure 2.

[16] Moving north-east along any 45° line represents increasing all prices while maintaining a constant difference between them. Because the marginal bid(s) is usually rationed, there is usually a single critical point that rejects the correct volume of bids. But if exactly £3 billion of bids can be rejected by rejecting entire bids, there will be an interval of points between the last rejected and the first accepted bid. As a tie-breaking rule, I choose the most south-westerly of these points.

[17] The initial vertical segment starts at the highest price for weak such that enough can be accepted on weak when none is accepted on strong (this price is the weak price of the bid for 680), and continues down as far as the highest price bid for strong (the strong price of the bid for 250). At this point some strong replaces some weak in the accepted set, and there is then a horizontal segment until we reach the next price bid for weak (the weak price of the bid for 345) where more strong replaces weak in the accepted set and another vertical segment begins, etc.

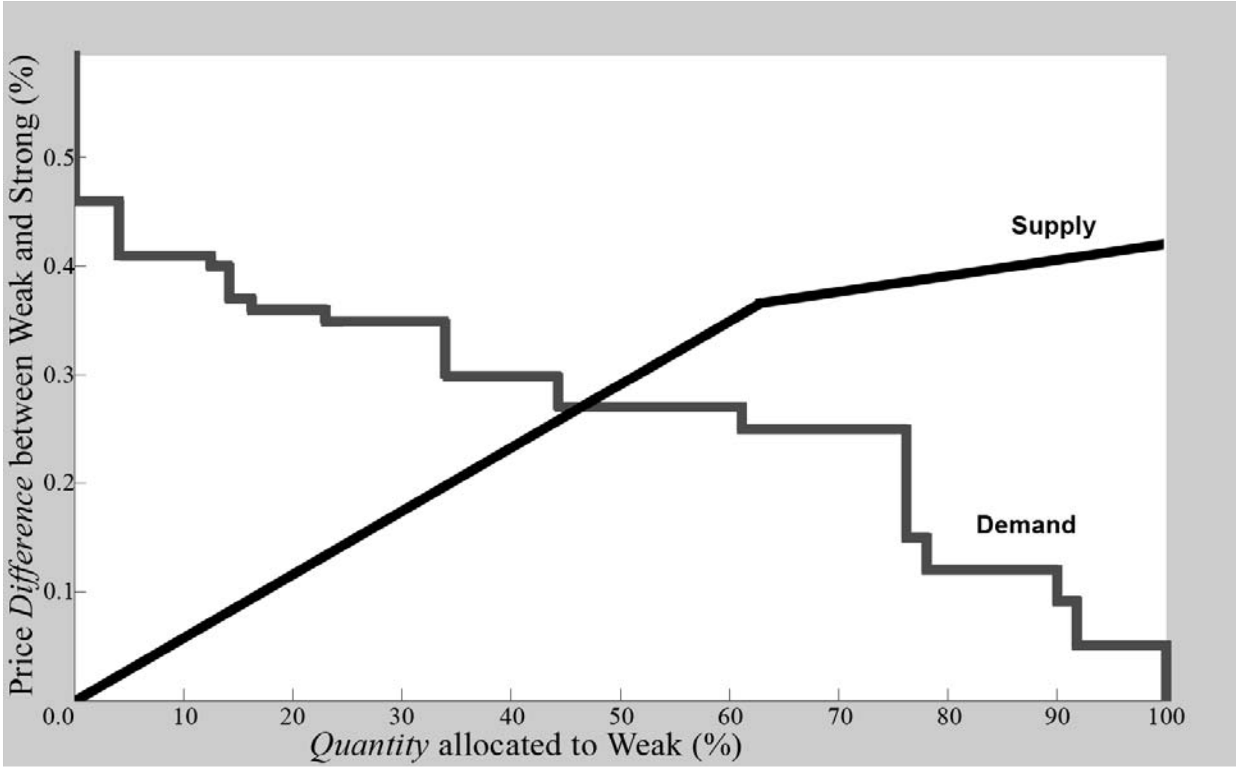

Figure 2: Equilibrium in the Bank of England's auction.

If it wished, the auctioneer (the Bank) could give itself discretion to choose any point on the "demand curve" (equivalently, any feasible rectangle in Figures 1a, 1b) after seeing the bids. In fact, the Bank prefers to precommit to a rule that will determine its choice. That is, the Bank chooses a "supply curve" or "supply schedule" such as the upward-sloping line in Figure 2 so the proportion allocated to weak increases with the price-difference.[18]

[18] The proposal for the U.S. TARP to employ a "reference price" for each asset corresponds to choosing the multi-dimensional equivalent of a horizontal supply curve; buying a predetermined quantity of each asset corresponds to using a vertical supply curve. As I noted above, both these approaches are flawed. Choosing an upward-sloping supply curve maintains the advantage of the reference-price approach, while limiting the costs of mispricing. (The optimal choice of supply-curve

The point of intersection between the Bank's supply curve and the "demand curve" constructed from the bids determines the price differential and the percentage of weak sold in the auction. With the supply curve illustrated, the price difference is 0.27% and the proportion of weak is 45% -- corresponding to the outcome shown in Figure 1a.[19]

This procedure ensures that bidders whose bids reflect their true preferences[20] receive precisely the quantities that they would have chosen for themselves if they had known the auction prices in advance. So unless a bidder thinks its own bids will affect the auction prices, its best strategy is to bid "truthfully"; if bidders all do this, and the Bank's supply curve also reflects its true preferences, the auction outcome is the competitive equilibrium.[21]

3. Easy Extensions

3.1 Multiple buyers and multiple sellers

It is easy to include additional potential sellers (i.e., additional lenders of funds, in our example). Simply add their maximum supply to the total that the auctioneer

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slope involves issues akin to those discussed in Poole (1970), Weitzman (1974), Klemperer and Meyer (1986), etc.; maintaining the reserve power to alter the supply curve after seeing the bids protects against collusion, etc., see Klemperer and Meyer (1989), Kremer and Nyborg (2004), Back and Zender (2001), McAdams (2007), etc.)

[19] By determining the proportion of weak, Figure 2 also determines what fractions of any bids on the rectangle's borders are filled, and the allocation between goods of any bids on the 45° line.

[20] This does not require pure "private value" preferences, but does not allow bidders to change their bids in response to observing others' bids.

We can extend our mechanism to allow bidders with "common values" to update their bids: the auctioneer takes bids as above, and reports the "interim" auction prices that would result if its supply were scaled up by some pre-determined multiple (e.g., 1.25). It then allows bidders to revise the prices of any bid that would win at the interim prices, except that the price on the variety that the bid would win cannot be reduced below that variety's interim price. Multiple such stages can be used, and/or more information can be reported at each stage, before final prices and allocations are determined -- we offered such an option to the U.S. Treasury, though it was not our main recommendation.

[21] Because on the order of 40 commercial banks, building societies, etc., bid in the Bank of England's auctions, it is unlikely that any one of them can much affect the prices. I assume the Bank's supply curve is upward sloping so, given our tie-breaking rule (see note 16), if there are multiple competitive equilibria the outcome is the unique one that is lowest in both prices.

sells, but allow them to participate in the auction as usual. If a potential seller wins nothing in the auction, the auctioneer has sold the seller's supply for it. If a potential seller wins its total supply back, there is no change in its position.

3.2 "Swappers" who might want to be on either side of the market

Exactly the same approach permits a trader to be on either, or both, sides of the market. If, for example, letting the auctioneer offer its current holdings of strong, a bidder in the auction wins the same amount of weak, it has simply swapped goods (paying the difference between the market-clearing prices).

3.3 Variable total quantity

Making the total quantity sold (as well as the proportions allocated to the different varieties) depend upon the prices is easy. The Bank might, for example, precommit to the total quantity being a particular increasing function of the price of strong. Using the procedure of Section 2 to solve for the strong price corresponding to every possible total quantity yields a weakly-decreasing function, and the unique intersection of the two functions then determines the equilibrium.

3.4 Other easy extensions

Several other extensions are also easy. For example, bidders can be allowed to ask for different amounts of the different goods in a bid. Or a bidder can specify that a total quantity constraint applies across a group of bids. And there can, of course, be more than two goods, with a cut-off price for each, and a bid rejected only if *all* its offers are below the corresponding cut-off prices.

Bidders can express more complex preferences by using several bids in combination: for example, a bidder might be interested in £100 million weak at up to 7%, and £80 million strong at up to 5%. However, even if prices are high, the bidder wants an absolute minimum of £40 million. This can be implemented by making all of the following four bids, if negative bids are permitted:

1. £40 million of {weak at maximum permitted bid OR strong at maximum permitted bid *less* 2%}.
2. £100 million of weak at 7%.
3. £80 million of strong at 5%.
4. *minus* £40 million of {weak at 7% OR strong at 5%}.

The point is that the fourth (negative) bid kicks in exactly when one of the second and third bids is accepted, and then exactly cancels the first bid for £40 million "at any price" (since 2% = 7% - 5%).[22]

4. Further Extensions, and the Relationship to the Simultaneous Multiple Round Auction

My auction is equivalent to a static (sealed-bid) implementation of a simplified version of a "two-sided" simultaneous multiple round auction (SMRA). (By "two-sided" I mean that sellers as well as buyers can make offers – see below.)

Begin by considering the special case in which the auctioneer has predetermined the quantity of each variety it wishes to offer, and the bids in my auction represent bidders' true preferences. Then the outcome will be exactly the same as the limit as bid increments tend to zero of a standard SMRA if each bidder bids at every step to maximize its profits at the current prices given those preferences,[23] since both mechanisms simply select the competitive-equilibrium price vector.[24]

[22] A bidder can perfectly represent any preferences across all allocations by using an appropriate pattern of positive and negative bids if the goods are imperfect substitutes such that the bidder's marginal value of a good is reduced at least as much by getting an additional unit of that good as by getting an additional unit of the other good (i.e., if $V(w,s)$ is the bidder's total value of £*w* of weak plus £*s* of strong, then $\partial^2 V / \partial w^2 \leq \partial^2 V / \partial w \partial s \leq 0$ and $\partial^2 V / \partial s^2 \leq \partial^2 V / \partial w \partial s \leq 0$). More general preferences than this require more complex representations--but the important point, of course, is that preferences can typically be well-approximated by simple sets of bids.

[23] In a SMRA the bidders take turns to make bids in many ascending auctions that are run simultaneously (e.g, 55% of 2.5 billion = 1.375 billion auctions for a single £1 of strong, and 45% of 2.5 billion = 1.125 billion auctions for a single £1 of weak). When it is a bidder's turn, it can make

The general case in which the auctioneer offers a general supply curve relating the proportions of the different varieties sold to the price differences is not much harder. We now think of the auctioneer as acting *both* as the bid-taker selling the maximum possible quantity of both varieties, *and* as an additional buyer bidding to buy units back to achieve a point on its supply curve. That is, in our example in which the Bank auctions £2.5 billion, we consider an SMRA which supplies £2.5 billion weak *and* £2.5 billion strong, and we think of the Bank as an additional bidder who has an inelastic total demand for £2.5 billion and who bids in exactly the same way as any other bidder.[25] [26]

So my procedure is equivalent to a "proxy SMRA", that is, a procedure in which bidders submit their preferences, and the auctioneer (and other potential sellers) submit their supply curves, and a computer then calculates the equilibrium that the (two-sided) SMRA would yield.[27] However, my procedure restricts the preferences that the auction participants can express. Although I can permit more general forms of bidding than those discussed above (see Klemperer, 2008),[28] some

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any new bids it wishes that beats any existing winning bid by at least the bidding increment (it cannot top up or withdraw any of its own existing bids). This continues until no one wants to submit any new bids. (For more detail, including "activity rules" etc., see, e.g., Milgrom (2000), Binmore and Klemperer (2002), and Klemperer (2004).)

[24] An exception is that an SMRA may not do this when bidders' preferences are such that they would ask for different amounts of the different goods in a single bid in my procedure. All the other types of bids discussed above reflect preferences such that all individual units of all goods are substitutes for all bidders (so bidding as described above in an SMRA is rational behaviour if the number of bidders is large). I assume the auctioneer also has such preferences (i.e., the Bank's supply curve is upward sloping), so if there are multiple competitive equilibria, there is a unique one in which all prices are lowest and both mechanisms select it (see note 21 and Crawford and Knoer (1981), Kelso and Crawford (1982), Gul and Stacchetti (1999), and Milgrom (2000)).

[25] That is, whenever it is the Bank's turn to bid, it makes the minimum bids to both restore its quantity of winning bids to £2.5 billion and win the quantity of each variety that puts it back on its supply curve, given the current price-difference. (It can always do this to within one bid increment, since the weak-minus-strong price difference can only be more (less) than when it last bid if its weak (strong) bids have all been topped, so it can increase the quantity of strong (weak) it repurchases relative to its previous bids, as it will wish to do in this case.)

[26] If there are other sellers (or "swappers") add their potential sales (or "swaps") to those offered in the SMRA, and think of these participants as bidding for positive amounts like any other bidders.

[27] Although Section 2's description may have obscured this, our procedure is symmetric between buyers and sellers. (It is not quite symmetric if the auctioneer doesn't precommit to its supply curve, but if bidders behave competitively their bids are unaffected by this.)

[28] I could in principle allow any preferences subject to computational issues; these issues are not very challenging in the Bank of England's problem.

constraints are desirable. For example, I am cautious about allowing bids that express preferences under which varieties are complements.[29]

Importantly, exercising market power is much harder in my procedure than in a standard SMRA, precisely because my procedure does not allow bidders to express preferences that depend on others' bids. In particular, coordinated demand reduction (whether or not supported by explicit collusion) and predatory behaviour may be almost impossible. In a standard dynamic SMRA, by contrast, bidders can learn from the bidding when such strategies are likely to be profitable, and how they can be implemented – in an SMRA, bidders can make bids that signal threats and offers to other bidders, and can easily punish those who fail to cooperate with them.[30] [31]

Finally, the parallel with standard sealed-bid auctions makes my mechanism more familiar and natural than the SMRA to counterparties. In contexts like the Bank of England's, my procedure is much simpler to understand.

[29] The difficulty with complements is the standard one that there might be multiple unrankable competitive equilibria, or competitive equilibrium might not exist (see note 24), and an SMRA can yield different outcomes depending upon the order in which bidders take turns to bid. In independent work, Milgrom (2009) explores how to restrict bidders to expressing "substitutes preferences". Crawford (2008)'s static mechanism for entry-level labor markets (e.g., the matching of new doctors to residency positions at hospitals) adddresses related issues in a more restrictive environment. See also Budish (2004).

[30] In a standard SMRA, a bidder can follow "collusive" strategies such as "I will bid for (only) half the lots if my competitor does also, but I will bid for more lots if my competitor does", see, e.g., Klemperer (2002, 2004), but in our procedure the bidder has no way to respond to others' bids. Of course, a bidder who represents a significant fraction of total demand will bid less than its true demand in *any* procedure, including mine, which charges it constant per-unit prices. But it is much easier for a bidder to (ab)use its market power in this way in an SRMA.

[31] A multi-round procedure (either an SMRA, or an extension of our procedure – see note 20) may be desirable if bidders' valuations have important "common-value" components, but may discourage entry of bidders who feel less able than their rivals to use the information learned between rounds.

5. Conclusion

The Product-Mix Auction is a simple-to-use, sealed-bid, auction that allows bidders to bid on multiple differentiated assets simultaneously, and bid-takers to choose supply functions across assets. It can be used in environments in which a simultaneous multiple-round auction (SMRA) is infeasible because of transaction costs, or the time required to run it. The design also seems more familiar and natural than the SMRA to bidders in many applications, and makes it harder for bidders to collude or exercise market power in other ways.

Relative to running separate auctions for separate goods, the Product-Mix Auction yields better "matching" between suppliers and demanders, reduced market power, greater volume and liquidity, and therefore also improved efficiency, revenue, and quality of information. Its applications therefore extend well beyond the financial contexts for which I developed it.

References

Ausubel, Lawrence, and Peter Cramton (2008). "A Troubled Asset Reverse Auction." mimeo, University of Maryland.

Ausubel, Lawrence, Peter Cramton, Emel Filiz-Ozbay, Nathaniel Higgins, Erkut Ozbay, and Andrew Stocking (2008). "Common-Value Auctions with Liquidity Needs: An Experimental Test of a Troubled Assets Reverse Auction." mimeo, University of Maryland.

Back, Kerry, and Jamie Zender (2001). "Auctions of Divisible Goods With Endogenous Supply." *Economics Letters,* 73, 29–34.

Budish, Eric (2004). "Internet Auctions for Close Substitutes." University of Oxford M.Phil. thesis.

Binmore, Ken and Paul Klemperer (2002). "The Biggest Auction Ever: the Sale of the British 3G Telecom Licenses." *Economic Journal*, 112, C74-C96.

Crawford, Vincent P. (2008). "The Flexible-Salary Match: A Proposal to Increase the Salary Flexibility of the National Resident Matching Program." *Journal of Economic Behavior & Organization*, 66, (2), 149-160, May.

Crawford, Vincent P., and Elsie Marie Knoer (1981). "Job Matching with Heterogeneous Firms and Workers." *Econometrica*, 49, 437-450.

Gul, Faruk, and Ennio Stacchetti (1999). "Walrasian Equilibrium with Gross Substitutes." *Journal of Economic Theory*, 87, 95-124.

Kelso, Alexander S. Jr., and Vincent P. Crawford (1982). "Job Matching, Coalition Formation, and Gross Substitutes." *Econometrica*, 50, 1483-1504.

Klemperer, Paul (1999). "Auction Theory." *Journal of Economic Surveys*, 13 (2), 227-86.

Klemperer, Paul (2002). "What Really Matters in Auction Design." *Journal of Economic Perspectives*, 16, 169-189.

Klemperer, Paul (2004). *Auctions: Theory and Practice*, Princeton University Press, Princeton, US.

Klemperer, Paul (2008). “A New Auction for Substitutes: Central Bank Liquidity Auctions, the U.S. TARP, and Variable Product-Mix Auctions.” mimeo, Oxford University.

Klemperer, Paul and Margaret Meyer (1986). "Price Competition vs. Quantity Competition: The Role of Uncertainty.”*Rand Journal of Economics,* 17, 618-638.

Klemperer, Paul and Margaret Meyer (1989). “Supply Function Equilibria in Oligopoly under Uncertainty,” *Econometrica*, 57, 1243-1277.

Kremer, Ilan, and Kjell Nyborg (2004). “Underpricing and Market Power in Uniform Price Auctions.” *Review of Financial Studies*, 17, 849-877.

Krishna, Vijay (2002). *Auction Theory*. New York, NY: Academic Press, US.

McAdams, David (2007). “Uniform-Price Auctions with Adjustable Supply.” *Economics Letters*, 95, 48-53.

Manelli, Alejandro M. and Daniel Vincent (1995). “Optimal Procurement Mechanisms.” *Econometrica,* 63, 591-620.

Menezes, Flavio M. and Paulo K. Monteiro (2005). *An Introduction to Auction Theory*. Oxford, UK: Oxford University Press.

Milgrom, Paul (2000). “Putting Auction Theory to Work: The Simultaneous Ascending Auction.” *Journal of Political Economy,* 108, 245-272.

Milgrom, Paul R. (2004). *Putting Auction Theory to Work*. Cambridge, UK: Cambridge University Press.

Milgrom, Paul (2009). “Assignment Messages and Exchanges.” *American Economic Journal: Microeconomics,*1, 95-113.

Poole, William (1970). “Optimal Choice of Monetary Policy Instruments in a Simple Stochastic Macro Model.” *Quarterly Journal of Economics*, 84, 197-216.

Weitzman, Martin (1974). "Prices vs. Quantities." *Review of Economic Studies*, 41, 477-491.