An analysis of the UK gold auctions 1999–2002

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This article examines bidding data for the 17 gold auctions held by the Bank of England on behalf of HM Treasury between July 1999 and March 2002. It employs information on auction participation to evaluate the outcomes of the auctions. Consistent with earlier studies it finds that the prices achieved at the auctions overall were in line with prevailing market prices. The article shows that uncertainty about future gold price movements was an important influence on the outcomes of particular auctions, although no single factor can explain why some auctions resulted in greater demand than others.

Introduction

On 7 May 1999, HM Treasury (HMT) announced a restructuring of the UK government's foreign currency and gold reserves involving the sale of part of the gold reserves through a programme of auctions.(1) The first of the auctions, which were on a single or uniform-price basis,(2) was held in July 1999. Thereafter, auctions were held at approximately two-month intervals until March 2002; there were 17 auctions in all. In the announcement, the government said that its intention was to reduce its holdings of gold, then around 715 tonnes, to around 300 tonnes in the medium term. Approximately 395 tonnes of gold were sold via the auctions, at an average price of around $275 an ounce.(3)

HMT has published a *Review of the sale of part of the UK gold reserves* (October 2002).(4) The *Review* describes, among other things, the rationale for the sales programme; the reasons why it was decided to sell gold by means of auctions, specifically uniform-price auctions; and the impact of the sales on the risk characteristics of the reserves portfolio. None of those issues is discussed in any detail in this article. Reports on the gold sales programme have also been produced by the National Audit Office (NAO) (January 2001),(5) and by the House of Commons Public Accounts Committee (December 2001).(6) The focus of those reports was on assessing whether the sales programme had achieved value for money for the UK taxpayer.

This article uses the detailed bidding data for the auctions, market price data, and measures of price uncertainty to conduct an analysis of the auction outcomes. The first section describes the design of the auctions and the administrative arrangements that governed them. The second explains the main features of the wholesale gold market, and developments within it, and in the gold price, during the course of the auction programme. The third section describes the aggregated bidding data and compares them across auctions. The fourth compares the outcomes of the auctions overall against a range of market price benchmarks in order to assess whether the auction prices were in line with those benchmarks. The fifth section analyses the outcomes of particular auctions in the context, in particular, of measures of uncertainty about the gold price.

Auction arrangements

The Bank of England acts as Agent for HMT in managing the Exchange Equalisation Account (EEA), the account which holds the United Kingdom's official foreign

(1) See www.hm-treasury.gov.uk/newsroom_and_speeches/press/1999/press_77_99.cfm.
(2) The box on page 189 discusses auction design issues, including the concept of uniform-price auctions.
(3) The trading unit for gold is the fine troy ounce; throughout this article 'ounce' shall refer to the fine troy ounce. There are 32,150.7465 ounces to the tonne. The average auction price was $274.9 per ounce and the revenue generated by the sales programme was therefore approximately $3.5 billion. The proceeds were retained within the foreign currency reserves and invested in interest-bearing assets.
(4) This is available at www.hm-treasury.gov.uk/media//9efef/goldreserves.pdf.
(5) *The sale of part of the UK gold reserves.* This is available at www.nao.gov.uk/pn/00-01/000186.htm.
(6) This is available at www.publications.parliament.uk/pa/cm200102/cmselect/cmpubacc/396/39602.htm.

Auction theory and design

Economists have long been interested in the design of auctions. This interest reflects both the wide range of economic situations in which auctions are employed as a selling mechanism (ranging from, for example, art works to telecommunication bandwidth) and the variety of auction formats that exist. Gold auctions, like government bond auctions, occupy a distinct category in that multiple units are sold (as opposed, for example, to a specific painting) and individual bidders typically have common knowledge about the valuation of the auctioned good. In the case of gold, potential bidders would all have been aware of the market price prior to the auction and were likely to have been influenced by common factors in establishing their expectations of the future market price. In such a situation, bidders are said to have common valuations.

Auctions of products such as government bonds are typically conducted via sealed bids (as opposed to the open bidding mechanism employed in many art house auctions). Bidders submit demand schedules, which consist of a price at which they are willing to buy and a quantity they are willing to buy at that price. In uniform or single-price auctions, all successful bidders pay the same price, generally the lowest accepted bid (or sometimes the highest rejected bid, or an average of all accepted bids). In discriminatory-price auctions, successful bidders pay the price they submitted in their own bids. Bids are accepted at successively lower prices, starting with the highest price, until the amount on sale is covered.

Auction theory suggests that bidders' strategic behaviour influences auction outcomes.(1) For example, in multiple-unit auctions, bidders generally have an incentive to lower (or 'shade') their demand schedules below their true valuations, that is, reduce the amount they bid for at each price. This is because a successful bidder is likely to conclude that his personal valuation was above the market consensus. This is referred to as the winner's curse. A rational bidder would be expected to take this into account when determining his bid price, and submit a demand schedule that is lower than his true demand schedule. In theory bid shading may occur in both uniform and discriminatory auctions.(2) The expected degree of shading is likely to be greater in a discriminatory auction, but auction theory cannot conclusively say which auction method will produce the greatest revenue for the seller, because bidders may also adjust the quantity demanded.(3) Under certain circumstances, expected revenue is greater in the case of a uniform auction, while in others it is greater in the case of a discriminatory auction. In the absence of any compelling theoretical arguments to favour one format over another, Binmore, in his report for the NAO, concluded that the use of a uniform-price format for the gold auctions made sense on the grounds of simplicity (bidding in uniform auctions is less complex) and market sentiment (market participants generally prefer uniform auctions).(4)

Both single and discriminatory-price auctions have been used in gold and government bond auctions, and their outcomes examined to assess the effects of different auction formats. For example, between 1976 and 1980, the International Monetary Fund conducted 45 gold auctions, ten as single-price auctions, and the remainder as discriminatory-price auctions. Research by Feldman and Reinhart (1995a and 1995b) concluded that shading was more prevalent in the discriminatory-price auctions, where auction prices achieved were, on average, about 1% below pre-auction market prices. Research on Swedish and Finnish Treasury auctions also suggested the presence of shading, but it was no more pronounced in the (Swedish) discriminatory-price auctions than in the (Finnish) single-price auctions.(5) Evidence from US Treasury bill auctions conducted in the early 1990s suggested that switching to a single-price method led in some cases to a drop in revenue, and in others to an increase.(6)

(1) See for example Binmore and Swierzbinski (2000).
(2) Practical, behavioural and market microstructural factors may nonetheless make auctions an attractive method of selling an asset such as gold. Some of these reasons are briefly discussed, in the case of gold, later in this article. NAO and HMT also note that auctions were a sales method well suited to meeting HMT's objectives for the sales programme of, among other things, selling in a transparent manner, and selling fairly. See NAO (2001), page 5, and HMT (2002), page 17.
(3) See for example Binmore and Swierzbinski (2000).
(4) See NAO (2001), Appendix 3, pages 40–44. HMT (2002), pages 18–20, sets out the reasons why a uniform-price format was chosen for the UK gold auctions.
(5) See Nyborg, Rydqvist and Sundaresan (2002) on the Swedish auctions and Keloharju, Nyborg and Rydqvist (2002) on the Finnish auctions.
(6) See for example Nyborg and Sundaresan (1996).

currency and gold reserves.[1] It was therefore the Bank that conducted the auctions on behalf of HMT. The Bank issued an Information Memorandum on 11 June 1999[2] setting out the arrangements for, and the terms and conditions governing, the gold auctions. The salient features are described below.

The auctions were conducted on a uniform-price basis, such that all successful bidders paid the same auction-clearing price. This price was determined as the lowest accepted bid price that allowed the Bank to allocate all gold on offer for sale.[3] All bids above the auction-clearing price were allotted in full, while bids made at the clearing price were pro-rated, if necessary. The pro-rata allocation was known as the 'scaling factor'.

Those entities eligible to bid were members of the London Bullion Market Association (LBMA),[4] central banks and other international monetary institutions that held gold accounts at the Bank.[5] The population of potential direct bidders was therefore limited. However, others wishing to bid were able to do so via one of the commercial banks that were eligible to bid directly.

Bids could be submitted either by authenticated SWIFT[6] message or in paper form, physically delivered to the Bank's banking counter. Bids were required to be received by the Bank not later than 11.30 am UK time on the day of the auction. The minimum bid size was 400 ounces (the approximate weight of a standard gold bar) and bids were required to be for multiples of 400 ounces. Prices bid were required to be in multiples of five cents per ounce bid. There was no limit to the number of bids that might be submitted by a single bidder, except that each bidder was permitted to submit no more than five bids in the ten minutes prior to the auction closing.[7]

The Bank published the results of each auction at 12.15 pm on the day of the auction, that is, 45 minutes after the auction had closed. In addition to the clearing price, the Bank published the cover ratio—that is the ratio of the sum of gold validly bid for to the amount on offer—and the scaling factor. The auctions settled two working days after the auction date. Settlement was by means of transfers from the gold account of the EEA to the accounts of the successful bidders.

With the exception of auctions held between September 1999 and September 2000, for which approximately four months' notice was given, precise auction dates were announced approximately two months ahead. At each of the first eleven auctions (held between July 1999 and March 2001), 25 tonnes of gold were offered for sale. At each of the final six auctions (held between May 2001 and March 2002), 20 tonnes were offered for sale.

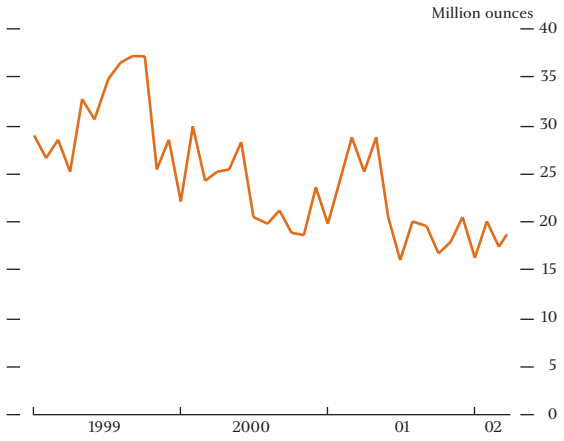
The wholesale gold market and market developments during the auction programme

Comparative international data for turnover by centre are sparse, but London is generally considered to be the most significant international centre for spot[8] and forward[9] dealing, lending, and trading of OTC[10] derivatives in gold. Certain commercial banks have the status of market-making members of the LBMA.[11] In terms of their activities in gold, market-making members are expected to provide two-way bid and offer quotations for spot and forward sales and purchases, options, and loans or deposits, throughout the London trading day.

Turnover data are available for activity in London, in the form of clearing statistics published by the LBMA. These data, shown in Chart 1, provide the total ounces transferred, both physically and in the form of account transfers, between those LBMA members that are part of

(1) Policy decisions about the reserves portfolio are taken by HMT. The Bank provides analysis and advice to assist HMT in making those decisions, implements the decisions that HMT makes, and manages the reserves on a day-to-day basis.
(2) The first Information Memorandum specified the arrangements for the auctions due to take place during the financial year 1999–2000. Subsequent Memoranda were published for the sales due to take place during the financial years 2000–01 and 2001–02 respectively. Other than described below, the arrangements did not change significantly.
(3) The Bank reserved the right to allot less gold than was offered for sale; it was of course also possible that the total amount of gold bid for at an auction might have been less than the amount on offer. Neither of these possible outcomes transpired during the programme.
(4) The LBMA is the main trade association for the international wholesale bullion market. A list of its members is available from its web site at www.lbma.org.uk. Those holding gold accounts at the Bank are chiefly commercial and investment banks.
(5) The Bank stores in its vaults gold belonging to a number of other central banks, international monetary institutions, and LBMA members.
(6) SWIFT is a secure electronic messaging system used in the wholesale financial markets. The great majority of bids was received by this means rather than in paper form.
(7) This restriction was imposed solely for logistical purposes.
(8) That is, for settlement in two working days' time.
(9) That is, for settlement beyond two working days' time.
(10) 'Over-the-counter', that is, a contract agreed bilaterally rather than transacted on a recognised exchange.
(11) A list of the current market-making members is available on the LBMA's web site.

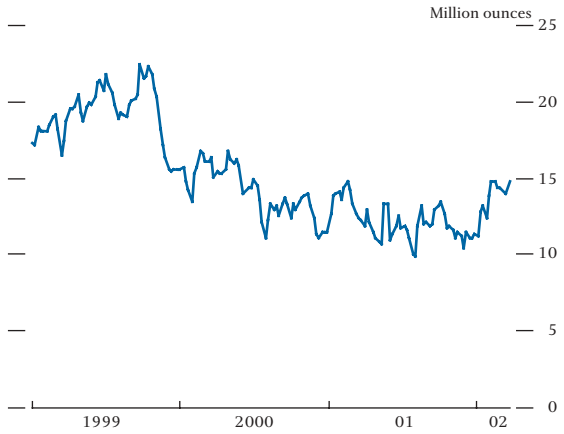
Chart 1
LBMA gold clearing data(a)
(January 1999–March 2002)



Source: LBMA.

(a) Monthly data.

Chart 2
Open interest in gold futures contracts traded on Comex(a) (January 1999–March 2002)



Source: Bloomberg.

(a) Weekly data.

the London clearing system for wholesale transfers. They are not a precise measure of overall market activity at any particular point in time since certain market transactions, such as forwards and options, may give rise to relatively small transfers of gold at the time they are executed, or none at all, or may not generate transfers until they mature.

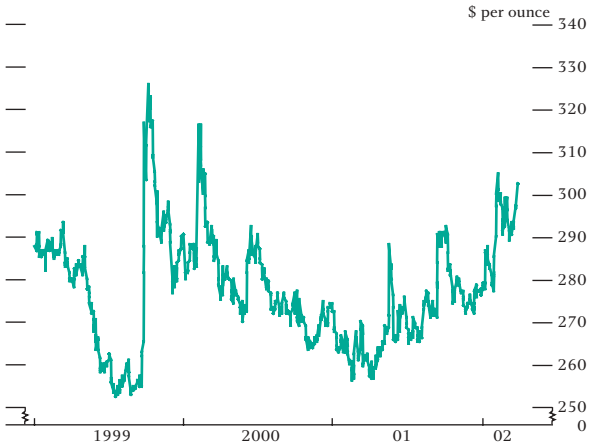
The most significant centre for exchange-traded contracts in gold futures and options is Comex, a division of the New York Mercantile Exchange (NYMEX), although there are other exchanges that offer gold products, notably Tocom, the Tokyo Commodities Exchange. Comex data for the 'open interest' on gold futures contracts are shown in Chart 2. This is the total number of contracts entered into by members of the exchange at a given point in time and not yet offset by transaction, delivery, exercise, etc.

It is notable that most of the available measures of turnover or market depth show a declining trend throughout the period of the auctions. This is consistent with comments from market participants that the liquidity of the market (in the sense of the size of transaction that could be executed without significantly moving the market price) and, perhaps relatedly, the amount of risk-capital allocated to trading activity in gold by participant institutions, were declining at this time. This was reflected in a reduction in the number of LBMA market makers, from twelve at the end of 1999 to nine at the end of 2001, and in the decision to reduce the amount of gold on offer from 25 tonnes to 20 tonnes at the final six auctions.

The standard market benchmark gold price is the London fixing price. The fixing takes place twice every business day, at 10.30 am (the 'AM fixing') and 3.00 pm (the 'PM fixing') UK time. The five fixing members, who are commercial banks active in the wholesale market, declare their interest (if any) to buy or sell gold, and the price is adjusted until their interests are approximately matched. At that point the price is 'fixed', and the fixing price published. As noted above, LBMA market makers, and other market participants, will quote gold spot prices throughout the trading day. Fixing prices are typically close to spot mid-prices prevailing around the time of the fixing. Differences may occur, for example because the fixing process itself reveals information relevant to price formation.

The London AM fixing was within a range of $252.90–$326.25 per ounce during the period of the auction programme. As can be seen from Chart 3, there

Chart 3
The gold price during the auction programme(a)
(January 1999–March 2002)



Source: Bloomberg.

(a) London AM fixing.

were certain sharp movements in the price. The first, and most notable, followed the announcement of the Central Bank Gold Agreement (CBGA) on 26 September 1999.(1) Under the CBGA the signatory central banks agreed that, during the five-year term of the Agreement, they would not enter the market as sellers, with the exception of sales already determined; that such sales would total no more than 2,000 tonnes in total and no more than approximately 400 tonnes per annum; and that they would not expand their gold lending or their use of gold futures and options. The Bank, on behalf of the UK government, was a signatory to the CBGA.

The second sharp rise in the price of gold occurred in February 2000, and was associated with market speculation that certain gold producers who had previously followed strategies to sell their output forward might have changed their approach.

A description of the auction data

In this section, aggregated bidding data are examined and compared across auctions. Table A presents information on participation in the 17 auctions. The number of bidders ranged from 15 to 23, with an average of 19. The number of bids per auction averaged 113, but varied considerably between auctions, from a low of 63 to a high of 197. Bidders at a particular auction tended to submit more than one bid. Very often these bids were at different prices. Such bundles of bids by the same bidder at a particular auction can be interpreted as demand schedules. Across all the auctions there were 317 such demand schedules, of which 275 consisted of more than one bid. The average number of bids in a demand schedule was six. Finally, the average bid size per auction, measured as a proportion of the total amount of gold on offer, varied from a low of 1.7% to a high of 5.2%, with an average of 3%. These averages mask a variety of bidding practices. Some bidders typically submitted a large number of small bids, while others tended consistently to submit a smaller number of larger bids.

The *cover ratio*, defined as the ratio of the sum of gold validly bid for to the amount on offer, is commonly used as a measure of auction interest. However, some care is required in interpreting this measure for the UK auctions, for a number of reasons. In particular, as noted above, the amount of gold on offer altered from 25 tonnes in each of the first eleven auctions to 20 tonnes in each of the final six. It is reasonable to assume that potential bidders adjusted their bidding behaviour in the light of the reduced amount of gold on offer; but it remains the case that, for a given sum of gold bid for, the cover ratio would have been higher in any of the final six auctions than in any of the first eleven. From Chart 4, it can be seen that all 17 auctions had a cover ratio greater than one, that is they were oversubscribed. The average cover ratio was 3.5, the maximum 8, and the minimum 1.3. It should be noted that the various minima and maxima noted in Table A (panel A) were not necessarily observed at the same auctions.

Rank correlations, shown in panel B of Table A, indicate that the level of the cover ratio was influenced more by the number of bids and the average bid size than by the number of bidders.(2)

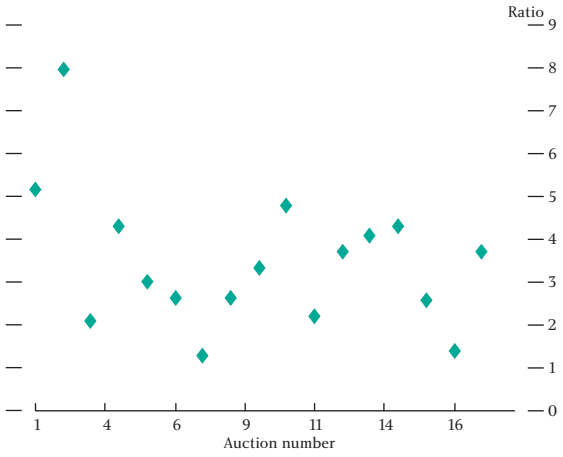
Table A
Summary statistics

Panel A: Summary statistics	Average	Minimum	Maximum
Cover ratio	3.5	1.3	8.0
Number of bidders per auction	19	15	23
Number of bids per auction	113	63	197
Number of bids per bidder	6	1	33
Average bid size per auction (per cent) (a)	3.0	1.7	5.2
Panel B: Rank correlation coefficients			
Cover ratio, number of bidders per auction	0.53		
Cover ratio, number of bids per auction	0.73		
Cover ratio, average bid size (a)	0.79		

Source: Bank of England.

(a) As a proportion of total gold on offer.

Chart 4
Cover ratios



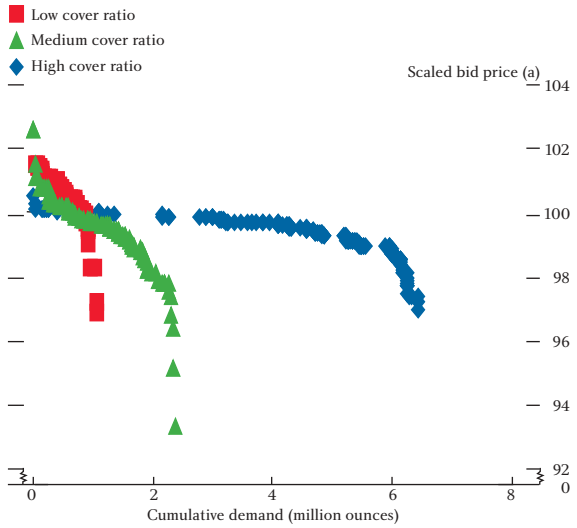
Source: Bank of England.

(1) The 15 signatories were the European Central Bank, eleven euro-area National Central Banks, the Swedish Riksbank, the Swiss National Bank, and the Bank of England. The Agreement is available at www.ecb.int/press/pr990926.

(2) Spearman's rank correlation coefficients in Tables A–C compare the rankings of two sets of variables. For example, the measure allows us to establish whether auctions with a higher cover ratio also tended to be auctions with a greater number of bidders. A high and positive coefficient would tell us that this was indeed the case. A negative coefficient would suggest that auctions with a high cover ratio were more likely to be those with a low number of bidders. Finally, a coefficient close to zero would indicate little relationship between the rankings of the two series.

As an alternative indicator of auction interest, one can construct aggregate demand curves that relate the prices and amounts bid for by all auction participants. The shape of the demand curve can be informative, as it provides a detailed picture of the range of prices auction participants were considering. Chart 5 shows examples of three such aggregate demand curves, chosen from among those auctions with relatively high, medium and low cover ratios respectively. The chart clearly shows that the auction with the higher cover ratio was characterised by a flatter curve, reflecting not only the greater amount bid for, but also a tighter range of bid prices.

Chart 5
Aggregate demand schedules



Source: Bank of England.

(a) Bid prices were scaled by the auction-clearing price.

Evaluating the auction outcomes overall

As explained in the box on page 189, auction theory suggests that bidders may bid below their personal valuations in order to avoid the winner's curse. This is because successful bidders, by definition, have made the highest bids, and may therefore conclude that the market 'consensus' was below their own valuations. For this reason, bidders may lower their bids below their true valuations (this is referred to as 'shading'). If all bidders engage in this practice, then the auction price will be a downwardly biased estimate of the true value, and auction revenues will be lower than fair value would imply.

However, there may also be reasons why a potential bidder would rationally be prepared to pay a premium over the prevailing market price to buy gold through the mechanism of an auction. One potential advantage of an auction is that bidders need only reveal their identity to the seller, rather than to others in the market. This could be attractive, for example, when a buyer is intent on purchasing a relatively large quantity of gold, and may be concerned that to do so openly in the market would move the market price against him. More broadly there is an argument that the selling of an asset such as gold by an official seller in a transparent and predictable manner, such as via auctions, may increase revenue, relative to other sales methods, by reducing the risk premium priced in by the market, encouraging participation, and allowing investors to plan their strategies ahead of the sale.(1)

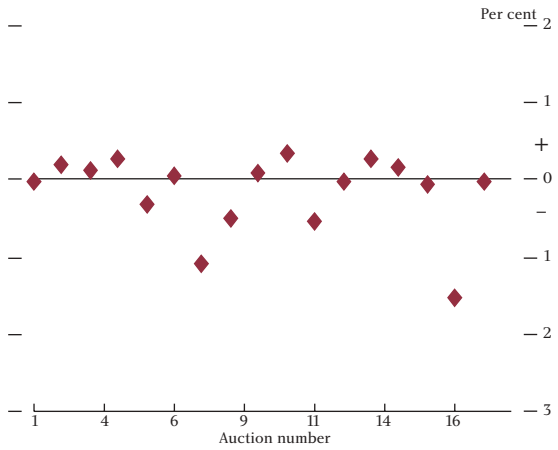
Since bidders' true valuations are of course unobservable, it is customary to estimate the amount of undervaluation (shading) or overvaluation in an auction price by measuring the difference between auction prices and market prices prevailing just before or after the auction. However, it is important to note that this comparison is at best imperfect. The gold market is relatively small, so that the amounts sold by the United Kingdom were not an insignificant proportion of market turnover during the day or even the week of the auctions. It is therefore possible that the benchmark market price would have been different had the UK sales taken place through a different mechanism.

Chart 6 and Table B (panel A) show the differences between auction and pre-auction prices, using the AM London fixing as a benchmark.(2) On average, auction prices were 0.2% below the AM fixing on the day of the auction. In nine auctions the auction price was below the AM fixing (the largest discount being 1.5%), whereas in the other eight auctions, the auction price was slightly higher (the maximum premium being 0.3%).

Table B (panel B) shows a positive and reasonably close correlation between measures of the difference (or margin) between auction and pre-auction prices in particular auctions, and the cover ratios of those auctions. This positive rank correlation coefficient shows that those auctions with positive (or less negative) margins between auction and pre-auction prices tended to have higher cover ratios, whereas those with more negative margins tended to have somewhat lower cover

(1) These issues are discussed in HMT's *Review* (2002), pages 17–18. There is a general discussion of transparency in O'Hara (1995) and Ganley *et al* (1998).
(2) Again, it should be noted that the various minima and maxima noted in panel A of Table B were not necessarily observed at the same auctions.

Chart 6
Auction price relative to AM fixing(a)



Sources: Bank of England and Bloomberg.

(a) Computed as the difference between the auction price and the AM fixing, scaled by the AM fixing.

Table B
Auction prices

Panel A: Summary statistics	Average	Minimum	Maximum
Auction price ($ per ounce)	275.2	255.75	296.5
Auction price relative to AM fixing (per cent)	-0.2	-1.5	0.3
Auction price relative to PM fixing (per cent)	0.1	-1.2	1.4
Auction price relative to 1 pm mid price (a) (per cent)	-0.1	-0.7	0.4
AM fixing - PM fixing (b) (per cent)	0.1		
(confidence interval (c))	(-1.0 to 1.2)		

Panel B: Rank correlation coefficients of cover ratio (d)	
Auction price relative to AM fixing	0.72
Auction price relative to PM fixing	0.12
Auction price relative to 1 pm mid price (a)	0.10

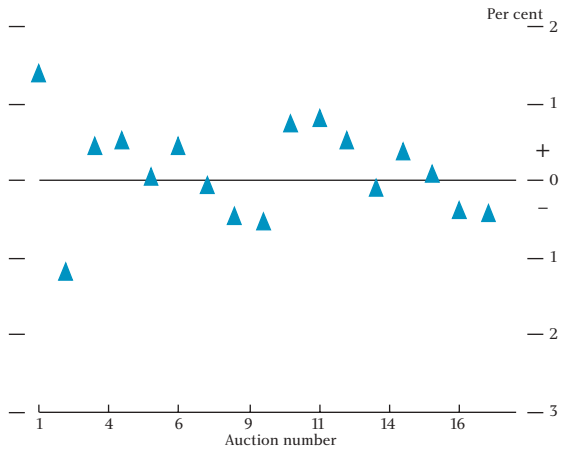
Sources: Bank of England and Bloomberg.

(a) The mid price is the average of the bid and ask prices.
(b) Calculated as the difference between the AM and PM fixing prices scaled by the average of the AM and PM fixing prices.
(c) Two standard deviations above and below mean.
(d) In panel B, a positive correlation coefficient indicates that a larger cover ratio was associated with less undervaluation or more overvaluation.

ratios. In other words, the higher the cover ratio, the less was the amount of undervaluation. This suggests that auction participants were less likely to bid away from their true valuations when bidding interest was high.

An alternative way of measuring the prevalence of either undervaluation (shading) or overvaluation is to examine the difference between the auction price and a post-auction market price. If the market price immediately after the auction were significantly higher than the auction price, that might indicate that auction bidders systematically bid below their true valuations, although it could also of course be the case that the outcome of the auction (both the auction price and the cover ratio) contained new information not previously reflected in market prices. Chart 7 uses the PM fixing

Chart 7
Auction price relative to PM fixing(a)



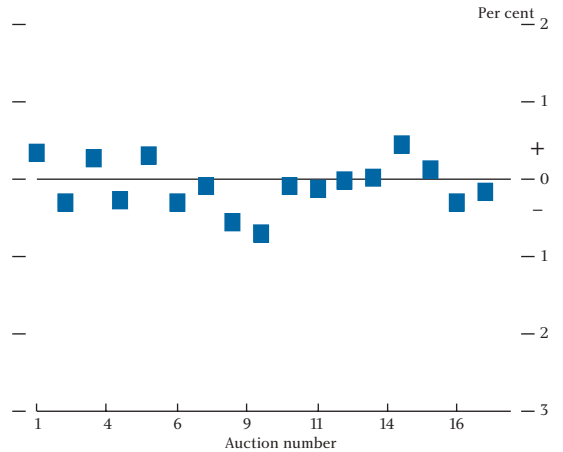
Sources: Bank of England and Bloomberg.

(a) Computed as the difference between the auction price and the PM fixing, scaled by the PM fixing.

on the day of each auction as a post-auction price benchmark. On average, auction prices were 0.1% above the PM fixing. The variance of the margins between the PM fixing and the auction price was somewhat greater than the variance of the margins between the AM fixing and the auction price, ranging from -1.2% to 1.4%.

A third possible benchmark is the spot market price just after the announcement of the auction results. This comparison is shown in Chart 8 below for the spot market price at 1 pm on the day of each auction. On average, this price was 0.1% below the auction-clearing price. Spot market prices at 1 pm were below the auction price in six out of 17 auctions, though the range of price differences was small.

Chart 8
Auction price relative to 1 pm spot price(a)



Sources: Bank of England and Bloomberg.

(a) Computed as the difference between the auction price and the 1 pm spot price, scaled by the 1 pm spot price.

The rank correlation coefficients of the cover ratio and the margin between auction prices and post-auction prices in Table B are much lower than that using pre-auction prices as the benchmark, implying a weaker relationship between post-auction price movements and auction interest.

Further evidence that auction prices did not deviate substantially from prevailing market prices can be obtained from comparing the above differences with typical intraday price movements. The average daily percentage change between the AM and PM fixing prices has been calculated for this purpose, together with a confidence interval. Both are reported at the bottom of panel A in Table B. According to this, the differences shown in Charts 6 to 8 were not inconsistent with typical price movements.

Analysing particular auction outcomes

The evidence in the previous section suggests that on average the auction prices achieved were close to their respective benchmarks.(1) But it also revealed some differences in the outcomes of individual auctions. This section investigates the extent to which the behaviour of auction participants, and conditions in the broader market, explain these differences.

Auction theory predicts that the more uncertain bidders are about the accuracy of their own valuations, the greater their concern about the winner's curse is likely to be. Their exposure to the winner's curse may be mitigated in three ways. First, bidders may shade their bids more, leading to greater discrepancies between auction prices and relevant benchmarks. Second, they may reduce the quantity demanded. And third, they may increase the range of their bid prices (recall that bidders can submit multiple bids or demand schedules).

Submitting a wide range of bid prices provides bidders with additional protection against the winner's curse.(2) This follows because, *ex post*, bidders would like to obtain more units of the auctioned good when the auction-clearing price (which summarises all bidders' valuations) is high relative to their own valuations, and fewer when the clearing price is low. With a wider range of bid prices, bidders have a greater probability of achieving this desired outcome: they will win more bids when the auction price is above their own average bid, and fewer bids when the auction price is below their own average bid. When uncertainty is greater, there is more value in this form of insurance and, consequently, bidders are likely to increase the dispersion of their bid prices.

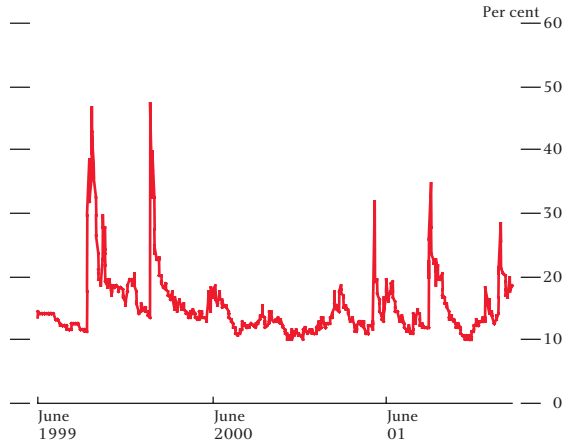
In sum, auction theory suggests that as uncertainty increases, bidders are likely to increase the degree of undervaluation in their bids (or reduce the degree of overvaluation), reduce the quantity they demand, and/or submit a wider range of bid prices.(3)

Auction theory also suggests that the number of bidders directly affects the auction price. Individual bidders face a trade-off as a result of competition from other auction participants.(4) If, on the one hand, a bidder decides to submit a higher demand schedule (ie increase the prices of all his bids), then he is more likely to win the auction, but he is also more exposed to the winner's curse, as in doing so he will have bid up the auction price. If, on the other hand, he lowers his demand schedule, then he reduces his chances of winning, but also lowers the auction-clearing price. This trade-off is less severe when the number of auction participants is larger, and the competition greater. Hence, theory predicts that auction participants will scale down their bid prices less in better-attended auctions, and more in less-attended ones. For similar reasons, the presence of a greater number of bidders is likely to encourage bidders to demand greater quantities and to submit a tighter range of bid prices. These propositions are tested below.

Uncertainty about future gold prices can be measured by the implied volatility derived from the prices of gold options. This is a forward-looking measure of investor uncertainty. For completeness, the analysis has been repeated with a historical volatility measure, using daily spot prices.(5) Chart 9 shows that implied volatility peaked a number of times, most notably after the

(1) This is consistent with the finding of the National Audit Office (NAO) that the auction prices achieved at the first nine auctions were in line with prevailing market prices. The NAO compared the auction prices with the PM fixing. See *The sale of part of the UK gold reserves*, page 19. HMT's *Review of the sale of part of the UK gold reserves* (page 22) extended this analysis to the entire auction programme and concluded that 'the prices achieved were competitive and in line with what might have been expected had an alternative route been chosen for the sale of gold'.
(2) Related to the winner's curse is the so-called champion's plague, which arises in multiple-unit auctions only and describes bidders' dissatisfaction at obtaining more units than their competitors.
(3) See for example Nyborg *et al* (2002).
(4) See for example Kremer and Nyborg (2002).
(5) This is computed from daily spot prices, using a Garch statistical model.

Chart 9
Implied gold price volatility



Note: Implied volatility from one-month gold options.

Source: UBS.

September 1999 and January 2000 auctions. The background to this price volatility is set out on pages 191–92 above.

Table C (panel A) suggests that greater uncertainty about the gold price ahead of particular auctions was associated with a greater degree of undervaluation (compared with prevailing market prices) at those auctions. The degree of association was stronger when historical volatility, rather than implied volatility, was used as a measure of uncertainty. Related to this, Table C (panel A) and Chart 10 show that uncertainty (as measured by implied volatility) was higher in the week leading up to some of the auctions with relatively lower cover ratios.

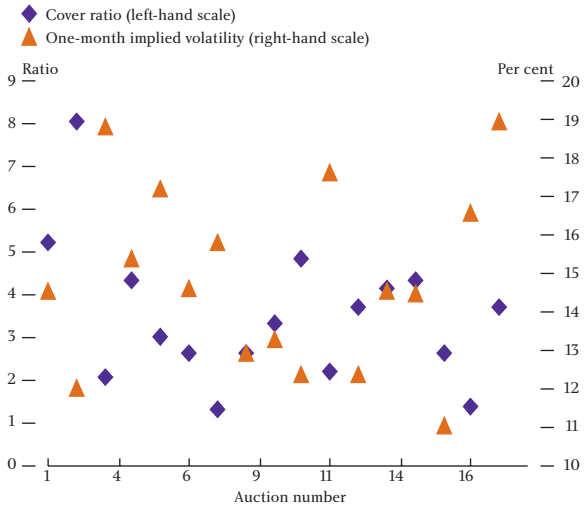
Table C
Rank correlations

Panel A: Uncertainty (a)	Implied volatility (b)	Historical volatility (c)
Auction price relative to AM fixing	0.32	0.47
Bid dispersion (d)	0.44	0.26
Average bid size	0.38	0.30
Cover ratio	0.44	0.45
Panel B: Number of bidders (e)		
Auction price relative to AM fixing	0.46	
Bid dispersion (d)	-0.12	
Average bid size	0.13	

(a) In panel A, a positive correlation coefficient indicates that greater uncertainty was associated with a greater discount or a lower premium relative to the AM fix, greater bid dispersion, lower bid size and lower cover.
(b) Measured as the average of daily implied volatility one week prior to auction.
(c) Measured as the average of daily historical volatility one week prior to auction.
(d) Computed as the difference between the highest and lowest bid price scaled by the average bid price.
(e) In panel B, a positive correlation coefficient indicates that a larger number of bidders was associated with a lower discount or a greater premium relative to the AM fix, lower bid dispersion and higher bid size.

Bid dispersion is shown in Chart 11, which plots the average bid price, together with the highest and lowest bid prices, for each of the 17 auctions. The chart

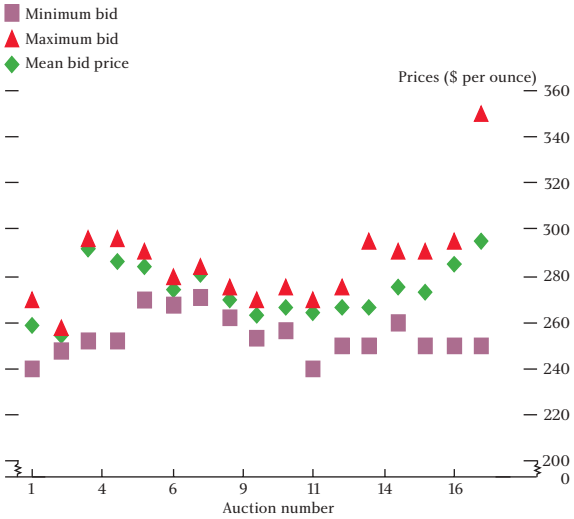
Chart 10
Cover ratios and implied volatility(a)



Sources: Bank of England and UBS.

(a) Average implied one-month volatility in week preceding auction.

Chart 11
Dispersion of bids



Source: Bank of England.

demonstrates that bid price dispersion varied substantially between auctions. Rank correlation coefficients in panel A of Table C indicate that these differences in price dispersion were related to differences in uncertainty, in that greater implied volatility was associated with more pronounced bid dispersion. Finally, Table C finds some evidence of correlation between uncertainty and average bid size.

Table C next relates the auction outcomes and the number of bidders. The results in panel B suggest that the number of bidders had some influence on the amount of over or undervaluation, but little influence on either price dispersion or average bid size.(1)

(1) Nyborg, Rydqvist and Sundaresan (2002), and Keloharju, Nyborg and Rydqvist (2002) reach similar conclusions.

Conclusion

This article has examined the outcomes of the 17 gold auctions conducted by the Bank of England on behalf of HM Treasury between July 1999 and March 2002. In line with previous research, it has found that, on average, the prices achieved in the auctions were in line with prevailing market prices. Drawing on insights from the theoretical literature on auction design, the article has gone on to examine factors that may have affected the outcomes of individual auctions. It has found that greater uncertainty about the gold price at the time of particular auctions was associated with a greater degree of undervaluation (compared with prevailing market prices) at those auctions, with lower bid sizes and with a wider dispersion of bid prices. There is some evidence that the presence of a relatively greater number of bidders at particular auctions was associated with less undervaluation at those auctions. But other aspects of bidder behaviour were unaffected by the number of auction participants.

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