Appendix 3 Lessons Learned from the UK 3G Spectrum Auction

Peter Cramton[2]

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In April of 2000, the Radiocommunications Agency of the United Kingdom completed its first spectrum auction, raising £22.5 billion for five third-generation (3G) mobile wireless licenses. This paper assesses how well the UK 3G spectrum auction did in achieving the Government's objectives.

I have been a major participant in spectrum auctions, since December 1993 when the United States was planning for its first spectrum auction. My involvement has been in all aspects of the auctions: advising governments on auction design, advising bidders on auction strategy, and conducting theoretical and empirical research. Since 1993, I have written over one-dozen research papers on spectrum auctions, which have been published in leading economic journals. I have advised several governments on spectrum auction design, including the United States, Canada, and Australia. I have also advised twenty bidders in spectrum auctions around the world. I have advised a bidder in nearly all of the 3G auctions conducted so far. In the UK auction, I advised One 2 One, which provided a glimpse of the UK auction process from design through execution.

Auctions have become the preferred method of assigning scarce spectrum to companies. The primary advantage of an auction is its tendency to assign the spectrum to those best able to use it. This is accomplished by competition among license applicants. Those companies with the highest value for the spectrum likely are willing to bid higher than the others, and hence tend to win the licenses. There are several subtleties that limit the efficiency of spectrum auctions. Still a well-designed auction is apt to be highly efficient. A second important advantage of auctions is that the competition is not wasteful. The competition leads to auction revenues, which can be used to offset distortionary taxation. Finally, an auction is a transparent means of assigning licenses. All parties can see who won the auction and why.

Since the mid-1990s, the United States has relied on auctions to award spectrum. Thus far, the Federal Communications Commission (FCC) has conducted thirty-four auctions. The auctions have performed well in assigning the scarce spectrum to its best use. Certainly, there have been some bumps along the road, but overall the auction program has been highly successful.

Many other countries, such as Australia, New Zealand, Canada, Mexico, Brazil, and India have also used auctions in the last five years. Many of these countries learned from the FCC's experience with spectrum auctions in deciding on a design of their own. The approaches taken have varied from country to country, and within a country from auction to auction. The most common approach is the simultaneous ascending auction, adopted by the FCC. Even within this broad format, there have been subtle differences that can play an important role in the auction's success.

Although the United Kingdom did not begin auctioning spectrum until 2000, it began with a bang. Its very first auction broke into the record books as the world's largest auction ever.

2 *This report was commissioned by the National Audit Office of the United Kingdom. The views expressed are my own.*

Objective

The Government's overall aim for the auction was "to secure, for the long term benefit of United Kingdom customers and the national economy, the timely and economically advantageous development and sustained provision of third-generation services in the United Kingdom." Subject to this, the Government's objectives were to:

1 Utilize the available spectrum with optimum efficiency;

2 Promote effective and sustainable competition for the provision of third-generation services; and

3 Subject to the overall objectives, design an auction that is best judged to realize the full economic value to customers, industry and the taxpayer of the spectrum.

My remarks will assess how successful the auction was in achieving the objectives above. First let me define how I interpret the three objectives above. As shorthand, I will refer to these objectives as efficiency, competition, and revenues.

Efficiency. I define efficiency as putting the spectrum in its highest-valued use. There are two steps in spectrum utilization: allocation and assignment. The allocation defines the licenses (the frequency band, the geographic area, the duration, and the restrictions on use). The assignment of the licenses is then determined by auction. I will address how both the allocation and auction design decisions likely affected efficiency.

My definition of efficiency is the broad notion of economic efficiency, rather than a narrow definition of technical efficiency. Technical efficiency focuses on providing services at minimal cost. From an engineering sense, this is best accomplished by a single network that avoids any duplication. However, from a practical viewpoint, competition can enhance the economic value of the spectrum by fostering innovation and better services. Thus, I do not view efficiency as directly in conflict with competition. A smaller competitor may well value its first 10 MHz of spectrum at more than the value of the last 10 MHz of spectrum won by a dominant incumbent. If so, efficiency dictates that the incremental 10 MHz of spectrum should go to the small competitor, despite any network duplication.

Efficiency should also take into account things like flexible use, resale, leasing, roaming, all of which can serve to promote efficient use. However, these topics are beyond the scope of this paper.

Competition. Competition refers to the market structure that results from the license assignment. The allocation and auction design play a critical role in determining this market structure. More competitive market structures are preferred, since they lead to greater innovation, better services, and lower prices. Competition is an essential goal for a government seeking to maximize social welfare. Generally, more competitors means more competition. However, because the provision of 3G services requires enormous fixed costs, there is a limit to how many competitors the market can sustain. Four strong competitors with more bandwidth may yield greater competition than six competitors with less bandwidth, especially if number five and six are weak.

Revenues. I interpret the Government's stated goal as a desire to maximize total surplus of the auction, taking into account its impact on consumers, industry, and the taxpayer. This goal is quite different from maximizing revenues. For example, one auction may attain higher revenues than another, but be inferior with respect to the government's objective if the revenue benefit to the taxpayer is more than offset by losses to industry and consumers. The goal as stated is an efficiency goal, rather than a revenue maximizing goal: create as much value as possible from the 3G auction for all participants in the economy. Raising revenues does have a potential efficiency gain, since auction revenues can be used to offset distortionary taxation. In the United States, economists have estimated the deadweight loss associated with taxation at about 33% (it costs the economy $1.33 to raise $1 in taxes). To the extent that auction revenues are not distortionary, then raising revenues has an efficiency gain. This is likely the case. Since the license fee is a sunk cost, it should have little impact on the 3G services or prices that are ultimately observed in the market.

For simplicity, I will define the revenue goal as maximizing revenues. However, this is not the goal as stated by the government in goal 3 above, nor do I believe that it is a desirable goal in itself. Rather revenue is a useful way to contrast alternative design choices. Efficiency and competition should be the ultimate objectives.

The UK auction format

The Government used a simultaneous ascending auction to auction five 3G licenses, A-E. The bandwidth for each license is as follows:

Bandwidth in MHz for each License

	A	B	C	D	E
Paired spectrum	2 x 15	2 x 15	2 x 10	2 x 10	2 x 10
Unpaired spectrum	5	0	5	5	5
Total	35	30	25	25	25

License A was set aside for a new entrant. Only potential new entrants could bid on this license. All bidders could bid on any of the remaining licenses (B to E). Licenses have a twenty year duration.

The simultaneous ascending auction used in the UK is a variation on the design used in the US. The UK design takes advantage of the especially simple license structure, namely the fact that each bidder can win at most one license. In contrast, most of the US auctions have had many regions and many licenses within each region, which greatly complicates bidding strategy. Here I provide only a brief description of the rules.

The auction worked as follows. All five licenses were up for auction at one time. The auction proceeded in a sequence of rounds. In each round, bidders that were not the current price bidder on a license could place a bid on a license, raising the price on that license by at least the minimum bid increment. At the end of the round, all bids and bidders were identified, together with the price bid (highest bid) and bidder for each license and the minimum bid in the next round. The auction continued until no bidder was willing to bid higher on any of the licenses. This format is a natural extension of the familiar English auction when selling multiple items with interdependent values.

There were several important details.

Associated bidders. The auction could have involved two phases. The first phase would have resolved conflicts among associated bidders, bidders that have an ownership interest in each other. In phase one, bidding would have occurred sequentially on a MHz basis until no associations remained. Then the group of now unassociated bidders would compete in phase two (the simultaneous ascending auction). This approach guaranteed that the five winners of the auction were unassociated. Indeed, all associations were resolved before phase one, so the auction actually began in phase two.

Spectrum cap. A company (or associated companies) could win at most one license. This guaranteed that there would be five distinct competitors for the provision of 3G services.

Deposits. Bidders were required to make an initial deposit of £50 million to enter the bidding. The deposit increased by £50 million when the bid exceeds £400 million. The deposit was intended to guarantee performance by winning bidders at the end of the auction. The deposit was fully refunded to losing bidders.

Payment. Winning bidders could either pay in full at the end of the auction, or pay in installments. However, the installment payment terms were sufficiently unattractive that all winners choose to pay in full.

Minimum opening bids. The minimum opening bids were:

Minimum Opening Bids (million £)

A	B	C	D	E
125	107.1	89.3	89.3	89.3

Minimum bid increments. To assure that the auction concluded in a reasonable amount of time, new bids had to exceed the price bid by at least the minimum bid increment. The increment was set as a percentage of the prior price bid. Bid increments fell as the number of bidders decreased.

Activity rule. A bidder had to be active in every round of bidding. A bidder was active in a round if: (1) it was the current price bidder, (2) it placed a bid on a license, or (3) it used a waiver. Bidders were given three waivers. This rule guaranteed that the auction progressed with each round of bidding. It also facilitated price discovery. The waivers allowed bidders to briefly pause their bidding. If a longer pause in the bidding was required, the bidder could call recess, which would stop all bidding for the rest of the day, and possibly the next day. Each bidder could call up to two recess days once the number of bidders had reduced to eight. A bidder that was the current price bidder was not allowed to bid on another license or raise its current price bid.

Number of rounds per day. A final means of controlling the pace of the auction was the number of rounds per day. The Government posted a schedule for the next day. The bidding began with few rounds per day, but increased as bidders became comfortable with the process.

Stopping rule. The auction ends if a single round passes in which no new bids or waivers are submitted on any license.

Bid information. The auction was fully transparent. Each bidder was fully informed about the identities of the bidders. Price bids and price bidders were posted after each round. In addition, all bids and bidder identities were displayed at the conclusion of each round, together with information on the use of waivers or recesses.

Bid withdrawal. Bids could not be withdrawn. A bid was an irrevocable commitment. This assured that the bids were serious.

Auction outcome

UK auction outcome

The UK 3G auction began on 6 March 2000 and finished on 27 April 2000, after 150 rounds and seven weeks of bidding. Thirteen bidders competed for the five licenses. All conflicts with associated bidders were resolved before qualification, so the bidding began in phase 2. The auction was the largest auction in history, raising £22.5 billion in revenues. This amount exceeded the total revenues of all US spectrum auctions conducted over the six years prior, which is remarkable given that the US is 4.5 times the size of the UK. The total amounts to 650 euros per person or 1100 euros per current subscriber.

The final winners and prices paid were:

Auction Winners and Winning Bids

	A	B	C	D	E
MHz spectrum	2 x 15	2 x 15	2 x 10	2 x 10	2 x 10
MHz Unpaired	5	0	5	5	5
Price Bidder	T/W	Vodafone	BT	121	Orange
Price Bid (£M)	4,385	5,964	4,030	4,004	4,095
£M/MHz paired	292	398	403	400	410

The prices exceeded the expectations of everyone: government, industry, bidders, and taxpayers. There is no question that the auction was successful in generating revenues.

Most of the bidders pursued a strategy of bidding on the license that represented the best value. Bidders thus switched from license to license as the prices changed. The exceptions were Vodafone and Orange, both of which staked out particular markets. Vodafone bid exclusively on the B license, the only large license available to incumbents. Vodafone often would use jump bids (bids above the minimum bid) to express its resolve in winning the B license. Even Vodafone's final bid was a jump bid. Orange staked out the E license, bidding exclusively on E, once the B license became too expensive.

The pricing dynamics were predictable, although certainly not the absolute level of prices. The prediction comes from understanding the existing market structure and how the auction works. First, there were four incumbents: Vodafone, BT, Orange, and One2One. Incumbents have much higher values than potential entrants. For an incumbent, the value of a license is the value of future 3G services plus the value of 2G revenues lost if it fails to secure a license. It is reasonable to suppose that consumers would prefer to get 2G service from an operator that has plans for 3G service. For an entrant, the value of a license is the value of future 3G services minus the cost of building a network. An incumbent's existing infrastructure reduces its 3G buildout cost. Finally, the more 2G customers an operator has, the easier it is to attract 3G customers. Thus, it is easy to predict that the four incumbents would each win a license, leaving the A license to the strongest new entrant. The second large license would go to either Vodafone or BT. These companies financially were the strongest and likely had the highest value for 3G services as a result of their much larger market shares compared with the younger incumbents. The two uncertainties were: (1) who was the strongest potential entrant, and (2) was Vodafone stronger than BT.

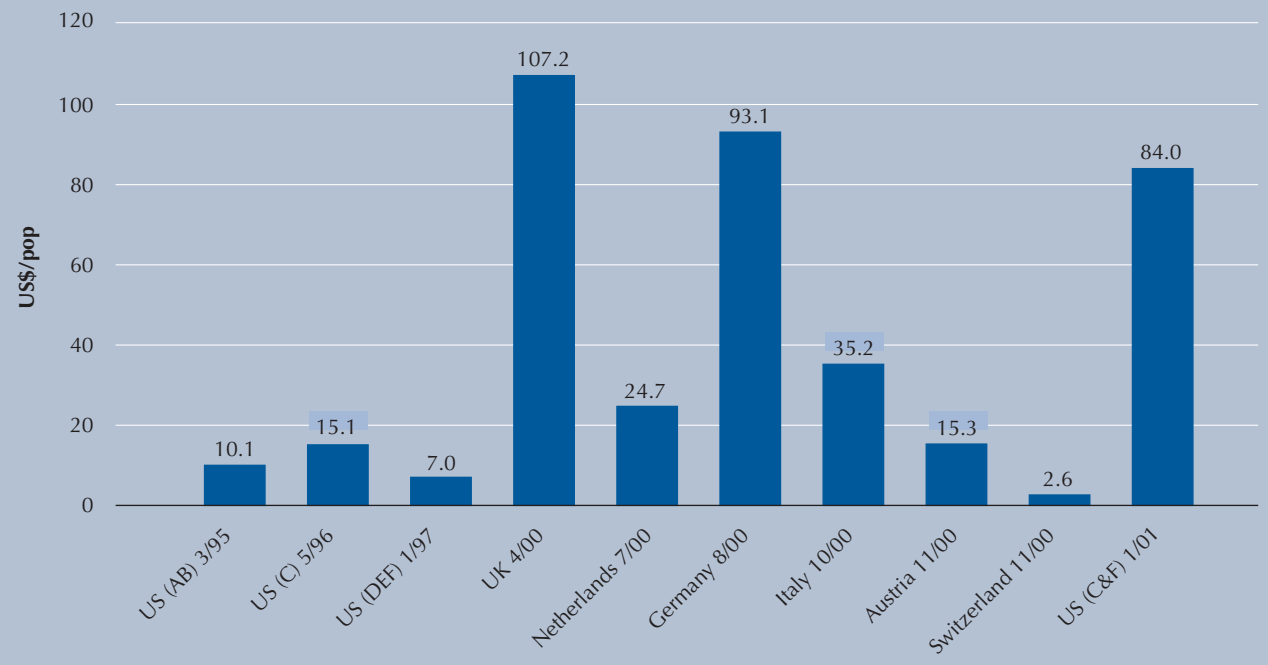
All the prices were effectively determined by two bidders: (1) NTL, the strongest among the eight unsuccessful new entrants, and (2) BT, the strongest among the three incumbents that failed to win a large license. NTL effectively set the price for C, D, E at just over £4 billion, when it dropped out of the auction in round 148. TIW's price for the A license was also set by NTL's arbitrage between the large A license and the smaller C, D, and E licenses. The bidding of NTL and the other new entrants indicated that the new entrants did not value the extra 5 MHz of paired spectrum very much. In contrast the two largest incumbents valued the extra 5 MHz a great deal. BT ultimately set the price for the B license when it placed its final bid on B in round 142. Vodafone's price per MHz was roughly equal to the prices paid for the small incumbent licenses (C, D, and E).

Contrast with other auction outcomes

Revenues in the UK 3G auction were the highest on a per person basis than any broadband spectrum auction to date. Auction prices have varied considerably over time and over markets. This is seen in Figure 1, which presents the per person price of a 20 MHz license (2 x 10 MHz paired) in several major spectrum auctions.[3] For comparison purposes, Figure 1 also shows past and current US auctions of 2G spectrum. The first three US auctions occurred over three years before the 3G auctions in Europe. The fourth US auction concluded in January 2001 with a price comparable to the highest 3G prices. Part of the price variation is explained by the different times at which the auctions occurred. Part of the difference in the European prices is explained by the size of the various countries. Markets like

3 Most of the European licenses also included 5 MHz unpaired spectrum. However, these auctions have shown that the bidders place little value on this unpaired spectrum, so I ignore the unpaired spectrum in the price comparison. In the US C-block auction, bidders received attractive installment payment plans. I discount these prices by 40% to reflect the value of the installment payments.

1 **Mobile Wireless Price Comparison (2x10 MHz + 5 MHz)**



the UK and Germany are thought to have more value, even on a per person basis, than the Netherlands and Switzerland. Still there is much variation to explain. The primary determinant of prices appears to be the level of competition going into the auction, rather than the subtle differences in auction design across the various countries. Competition in the auction is largely endogenous, since it is the result of partnership negotiations among potential bidders.

The two most recent 3G auctions have continued the slump in 3G prices. Both the Belgian auction and the Singapore auction ended after the submission of the initial bids at the reserve price. Neither auction had excess demand.

Why were prices so high?

A critical choice impacting revenues was the decision to auction five licenses. Five licenses guaranteed that a new entrant would win a license. This certainty that an entrant would win created a strong incentive for potential entrants, especially strong potential entrants to enter the bidding. Setting aside the largest license for a new entrant further intensified the incentive to enter. Not only would a new entrant win, but the successful entrant would win the best license.

The experience in the Netherlands illustrates the importance of having more licenses than incumbents in stimulating revenues. In the Netherlands, five incumbents bid for five licenses. The logical outcome was for the five incumbents to win licenses. Recognizing the difficulty of winning a license, potential entrants had a strong incentive to partner with an incumbent bidder. This is exactly what happened. Although initially there were several strong potential entrants, all partnered with one of the incumbents before the auction began. The strongest entrant, Deutsche Telecom, partnered with the weakest incumbent, Ben; DoCoMo and Hutchison partnered with KPN; and NTL was already effectively partnered with Dutchtone (France Telecom has a large interest in both). This left one weak entrant in the bidding. At the beginning of the auction, just six bidders were competing for five licenses: five strong incumbents and one weak potential entrant (Versatel). It was not long before the lone entrant gave up.

Two further factors were important in the high revenues achieved. Both have to do with the timing of the auction.

First, the UK auction was the first in the sequence of European 3G auctions. The largest wireless operators believed that winning a license in the UK was an important first step in becoming or sustaining a major position in Europe. The UK was the foot in the door to Europe and potentially the world. Generally, when bidding in a sequence of auctions for complementary items, the early items sell for more, since winning the early items gives the winner a competitive advantage in winning subsequent complementary items. Also, since it was the first auction, the bidders were unable to predict the extremely high prices that would result if they did not form alliances before the auction.

Second, the auction occurred at the peak of an apparent high-tech stock bubble. Wireless and other high-tech companies were being valued at all-time highs and at unheard of price-earnings multiples. Certainly for the incumbents, but also for the strongest new entrants, the question of value was transformed into a question of how much the stock price would be hurt if the company failed to win a license. With UK wireless companies being valued in

the tens of billions, paying four billion for entry into the 3G business seemed reasonable. In this way, the inflated stock market values had a direct impact on the companies' willingness to bid.

Finally, the ascending auction format coupled with the large excess demand likely contributed to high prices. First, the ascending format gave the bidders greater comfort in bidding higher, since they were able to see the large number of competitors that were willing to bid higher. In an ascending auction, dropping out is an admission of inferiority in some sense. Bidders ask themselves, "If the license is worth a lot to my competitor, why is it not worth a lot to me?" By bidding higher, the company does not concede it is inferior to its competitors. Second, an ascending auction over seven weeks gave the bidders ample time to go back to board to ask for additional money. Initial budget constraints were relaxed.

Choice of allocation

The decision to auction five licenses had a big impact on the competition objective in addition to its impact on revenues. Five licenses meant that there would be five 3G service providers. Moreover, the success of the new entrant was enhanced by setting aside the best license for the entrant. Hence, the allocation appears to be highly consistent with encouraging competition.

There were four other reasonable choices for the allocation:

1 Four licenses, each with 2x15 MHz.

2 Five licenses, two 2x15 and three 2x10, as in the UK, but without setting aside the best license for an entrant.

3 Six licenses, each with 2x10 MHz.

4 Twelve 2x5 MHz blocks, requiring that each winner win either two or three blocks.

The four-license option maintains the status quo of four incumbents. This would be desirable if the industry cannot support a fifth operator. However, the experience in the US and parts of Europe appears to suggest that five operators can operate profitably. The four license approach would likely result in the least competitive market structure. It also would likely lead to the lowest auction revenues.

The five-license option (without the best license set aside for a new entrant) does add another competitor in the wireless market. Moreover, unlike in the set-aside approach, the second large license would end up with the second-strongest incumbent (BT), rather than the entrant. This outcome is more efficient, since the second-strongest incumbent likely can make better use of the extra 5 MHz of paired spectrum. Revenues could be lower with this option, since Vodafone and BT would no longer have to compete for the only large license. The price for the large licenses would be set by Orange. Whether overall revenues would be higher or lower without the set-aside depends on how high Orange would be willing to bid for the extra 5 MHz. Based on the observed bidding, Orange only bid on the large license when the spread between large and small was less than about £450 million. This suggests that revenues would probably be slightly lower without the set-aside. BT forced a spread of nearly £2,000 million between large and small. If without the set-aside, Orange forces a split of only £500 million, then revenues would fall.

The six-license option is desirable if adding a sixth operator does foster competition. However, one must recognize that there are significant fixed costs in this industry. It is entirely possible that the number six entrant in the market is necessarily too weak to offer much in terms of service innovation or price competition. The issue is largely an empirical question that will take time to resolve. The German and Austrian auctions suggest that at least in the major markets there is room for six. Given the overwhelming evidence that greater competition fosters both service innovation and lower prices, the Government should err on the side of two many licenses, rather than too few. Adding a new entrant after the auction by splitting up an incumbent is almost impossible. Consolidation after the auction is much easier to implement.

Total auction revenues would likely be slightly lower with six licenses. There are two reasons. First, Telefonica would become the marginal bidder. In the five license auction, Telefonica dropped out at £3,668, compared with NTL's dropout at £3,971. All six licenses would sell for approximately Telefonica's dropout point. Second, Telefonica's dropout point would be less, since it would be bidding to participate in a six-player market as opposed to a five-player market. The difference in revenues, however, likely would not be large.

The auctioning of 5 MHz blocks, as was done in Germany and Austria, lets the bidders decide how many winners there should be. The number of winners would be between four and six under this approach. This approach would appear to be highly desirable, since the number of winners is determined by a competitive process. However, one might fear that there would be a strong tendency for the four incumbents to win all the spectrum, each getting three blocks. Incumbents have substantially higher values because of their incumbent position, and they benefit from excluding new entrants. However, it is possible that the incumbents would recognize that by only bidding on two blocks the auction would end at much lower prices. The incumbents in essence make room for two new entrants in order to keep the prices down. The question is whether the benefit from reducing demands more than compensates for the reduced profits in a six-player vs. a four-player market. Given the outcome in both German and Austria involved six winners, rather than four or five, it would appear that this design does not discourage entry too much. Another potential disadvantage of the German approach is that it does not

allow the bidders to bid on particular bands of spectrum. This can introduce an inefficiency if different bidders value the different bands differently.

A variation of the German approach would be to set aside two blocks for a new entrant and then let the bidding determine whether there would be four or five winners for the remaining ten blocks. This would guarantee at least five winners, and allow a six winner if the sixth bidder is willing to bid higher than the two strongest incumbents.

Choice of auction format

Based on the objectives of efficiency and competition, the Government made a wise choice of auction format.

The simultaneous ascending auction was highly efficient. The five winning firms demonstrated that they valued the spectrum more than the eight losing bidders. The only potential source of inefficiency was setting aside a large 15 MHz license for a new entrant. The bidding revealed that BT valued the extra 5 MHz more than the new entrant TIW. However, guaranteeing that the entrant would win a 15 MHz license and not be forced to pay BT's incremental value for 5 extra MHz likely was pro-competitive, both in the auction and in the post-auction market. The set-aside surely stimulated participation by potential entrants. Post-auction competition was also stimulated, since the new entrant (TIW) will be stronger and less capacity constrained as a result of the extra 5 MHz block. On balance, setting aside the largest license for a new entrant probably was a desirable tradeoff between competition and efficiency.

Contrast with the US auctions

The differences between the UK auction rules and those in the US auctions were minor. I list them below:

1 In the US, the current price bidder can raise its own bid. This was not allowed in the UK auction. Raising one's own bid typically is a bad strategy. Nonetheless, bidders in the US frequently have done so, especially early in the auction to stake out particular regions. I see little advantage or disadvantage in forbidding this practice of raising one's own bid.

2 In the US, as the percentage increment changes, the minimum bid on a license reflects the new increment immediately, regardless of whether the license receives a new bid in the round. In the UK, the minimum bid on a license would only be adjusted after the license received a new bid. Typically, reductions in the percentage increment occur after one or more bidders drops out of the auction. Since the licenses were all excellent substitutes it seems appropriate that all licenses should reflect the reduction in bid increment immediately, rather than waiting until after a license receives a bid. Still I do not believe that this difference had a significant impact on the outcome.

3 In the US, bid raises are a whole number of bid increments, from one to nine. In the UK, new bids could be any amount in tenths of a million between the minimum bid and the maximum bid. This enabled the UK bidders to make small jump bids. Since even small jumps are rare near the end of the auction, it is unlikely that this difference had any impact on the auction outcome.

4 The US does not use a "ratcheting deposit," as was used in the UK. Having the deposit increase with higher bids provides extra protection against default, but it does complicate the bidding mechanics. Non-performance is a serious concern. Still I believe that typically it is possible to set an appropriate deposit before the auction, and avoid the extra complication requiring the bidders to raise deposits as bids increase. In the UK auction, the complication was slight, since there was just a single increase in deposits when bidding reached £400 million.

5 The US auctions do not have an initial phase to eliminated associated bidders. Having the initial phase was probably a good idea in the UK, where bidder associations are more common than in the US. Although phase one was not used in the actual auction, it served as a useful threat point in the negotiations among associated bidders before the auction began.

6 The US does not allow a bidder to call a recess in the bidding. The recess feature potentially could add several days to the bidding. In fact, only one recess was used. This was by Telefonica when key members of the auction team were tied up in a major shareholder meeting. It is possible that recesses could be useful for bidders that need extra time to make critical decisions. However, in this particular auction, I believe that recesses were not important, since it was straightforward for bidders to estimate where prices were likely to be after another day or two of bidding and take appropriate actions.

None of the differences between the US auctions and the UK auction were significant. The outcome would have been essentially the same without any of the subtle differences.

Contrast with other 3G auctions

Three basic auction formats have been used in the 3G auctions.

1 The UK format. Used in the UK, the Netherlands, Switzerland, Belgium, and Singapore. Bidders bid on particular licenses in a simultaneous ascending auction.

2 The Italian format. Used in Italy. Bidders do not bid on specific bands. Hence, all licenses are identical at the time of bidding. A simultaneous ascending auction is used. When no one is willing to bid higher the auction ends with the four highest bidders receiving a license and paying their bids. The particular bands won is set at the end of the auction.

3 The German format. Used in Germany and Austria. Like in Italy, the bands are determined at the end of the auction. All blocks are identical at the time of bidding. Bidders bid for two or three 5 MHz blocks in a simultaneous ascending auction.

The Italian format only makes sense if the licenses are identical at the time of bidding. This was not the case in the UK, since the licenses were of different sizes. Moreover, bidders typically care about the particular band that they receive. To the extent that bidders preferences among the bands differ, then the Italian format introduces an inefficiency that is not present with the UK format. In most cases, the differences are small, so that the potential inefficiency is small. Otherwise, there is little difference between the UK and Italian formats.

As discussed above, the German format has the benefit of endogenous determination of license size and market structure. However, the bidding strategies are more complex and it is unclear whether the outcome is more or less efficient than with the UK format. Another important difference between the UK and German formats is that the German auction was not fully transparent. Only the current price bids and bidders were reported after each round, rather than all the bids. This made it more difficult for the bidders to observe when other bidders dropped from three blocks to two blocks. This may have stimulated auction revenues in Germany.

Denmark intends to conduct a sealed bid auction. I believe such an approach raises a significant possibility of an inefficient outcome.

Hong Kong is using a simultaneous ascending auction, but the bids are a combination of royalties and fixed fee. Royalties are problematic because they distort future business decisions and they require that the government monitor 3G revenues.

Auction implementation

The implementation of the auction was generally excellent.

My one complaint was the use of encrypted fax for the communication of bids, rather than using the Internet. Encrypted fax is a little used technology that is at best cumbersome. Software for conducting simultaneous ascending auctions using secure Web technologies is now readily available. The UK should use such software in future auctions.

Other matters of implementation are discussed below.

Qualification and deposits

The UK wisely kept qualification simple. Complex qualification makes sense in a beauty contest, but has no place in an auction. Rather substantial deposits were sufficient to keep out unqualified bidders. As it turns out, the initial deposits probably should have been larger. However, it was impossible to predict how high prices would ultimately go. The ratcheting deposits corrected this problem to some extent, but the maximum deposit (£100 million) was less than 2.5% of the final bid amount. Although a larger deposit may have been desirable, I do not believe that the small deposit adversely affected the outcome.

Pace of the bidding

The Government controls the pace of the auction through three main instruments: the minimum opening bids, the bid increments, and the rounds per day.

Minimum opening bids

In retrospect the Government could have set substantially higher minimum opening bids. However, given that this was the first 3G auction in the world, there was little information to gauge where prices would end up. The fact that the minimum opening bids were too low had essentially no adverse consequences. It simply meant that the auction continued for much longer in both rounds and days.

Low minimum opening bids can definitely be a problem in auctions where competition is weak. This was not the case in the UK.

A more serious mistake in setting minimum opening bids is setting the prices too high. Indeed, perhaps in response to the 3G auction, the UK Government may have set minimum opening bids too high in its next auction for fixed broadband wireless access. Many licenses went unsold in that auction.

Bid increments

Bid increments began at 5% and ultimately fell to 1.5%. There was little reason to begin with such a small bid increment. Given that there were eight extra bidders in the auction, the auction easily could have begun with an increment between 10% and 20%. Then the increment could be dropped to 5% once five or six bidders had dropped out. Higher bid increments would have meant that the auction could complete in about 50 to 75 rounds, rather than the 150 that was required. The auction would then have taken three weeks to conclude, rather than seven weeks.

Higher increments would not have hampered efficiency in any way. The increments still could have been dropped to the 2% level once the bidding was down to six bidders for the five licenses.

The cost of an excessively slow auction were not large. Given the enormous stakes, one can argue that the bidders needed time to assess how high to bid. Hence, although the auction could have been completed more quickly, taking 150 rounds and seven weeks did not result in any significant loss.

Rounds per day

The auction began with few rounds per day. This was gradually increased until a steady state of about six rounds per day was reached. It was difficult to have more rounds per day given the rather cumbersome bidding method using encrypted fax. In contrast, much larger and more complex auctions in the US have been conducted with many more rounds per day. Eight to twelve rounds per day has been common in recent US auctions.

Although the auction could have been conducted much faster, there was little economic loss from the gradual pace. The high stakes and great uncertainty about value probably justified the conservative course taking by the UK Government.

Impact on 3G roll-out

A major concern with the European 3G auctions is the enormous debt that has been acquired by the winners. Many fear that the high debt will adversely impact the timely roll-out of 3G services. As a result of the high auction prices, especially in the UK and Germany, companies have seen their share prices drop. Drops in debt ratings have also occurred, making it more difficult for companies to fund the cost of building the 3G infrastructure.

Payment for spectrum in the UK auction, as in all the European auctions, is structured as a one-time fixed fee. In theory this has the advantage that the fee, once paid, is treated as a sunk cost. Hence, its magnitude should not affect subsequent decision making by the companies. If the firms overpay for the spectrum, the predominant affect is a drop in share price. What services are provided and how they are priced should be independent of the fixed fee paid for spectrum.

In practice, excessive spectrum fees can have a negative impact on services. The reason is that at least in a short period of time capital markets cannot absorb an unlimited amount of debt. When there is excess demand for debt, then the terms become less attractive for the companies requiring debt. Companies may slow the pace of buildout in order to limit the acquisition of debt. This problem may be especially severe for new entrants that have greater buildout costs and only the prospect of future revenues. This is unfortunate since if the new entrants are weak the post-auction market will be less competitive. Excessively high auction prices can slow the roll-out of 3G services and reduce competition in the market for these services. The weaker operators may go bankrupt leading to a consolidation in the industry and a further slowing of access to 3G services.

If spectrum prices were excessive in the UK auction, it is difficult to blame the UK Government. The auction process was structured in such a way that the prices were largely determined by the strongest new entrant that failed to win a license. This bidder was NTL. The fact that incumbents were in a position where they had to win a license did not impact prices. Prices were determined by the marginal new entrant. Even if the UK auctioned six licenses, the price per license only would have been slightly less, and indeed total revenues may have increased.

Conclusions

The UK auction was highly successful in achieving the objectives of efficiency and competition. At the same time it raised considerable revenues. Even with 20-20 hindsight, it is difficult to make any suggestions that would have improved the outcome significantly.

The UK Government took great care in its choice of auction format. The auction was carefully designed and implemented. The Government made excellent use of outside experts throughout the auction process. The Government also made good use of the wealth of experience in other countries. The reward for the care taken was a highly successful auction process.