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The First Combinatorial Spectrum Auction: lessons from the Nigerian auction of fixed wireless licences

Richard Marsden, Christian Koboldt and Dan Maldoom

17 Welbeck Street
London W1G 9XJ
www.dotecon.com

The First Combinatorial Spectrum Auction

Christian Koboldt and Dan Maldoom and Richard Marsden*

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Abstract

In June 2002, Nigeria held a sealed bid combinatorial auction for regional fixed wireless access (FWA) licences. This was the first time that combinatorial bidding has been used for allocating radio spectrum. The choice of format was influenced by the outcome of an initial application stage, with bidders submitting potentially binding applications at a reserve price, which revealed information about the structure of bidder demand and inter-regional synergies. The format also met the significant logistical constraints of running a spectrum allocation procedure in Nigeria.

In this paper, we analyse the design, implementation and outcome of the allocation process. Some 67 of the 80 available licences were allocated, with successful bids totalling 3.78 billion naira (38 million US dollars). The process was widely praised within Nigeria for both its transparency and success in allocating licences.

Keywords: *Spectrum auctions; Combinatorial auctions; Multiple-item auctions; Auction design; Telecommunications; Transparency; Nigeria*

JEL classification: D44 (auctions), L96 (telecommunications), N47 (Africa)

*DotEcon Ltd, 105-106 New Bond Street, London W1S 1DN, phone +44-20-7870-3800, fax +44-20-7870-3811, email: richard.marsden@dotecon.com / christian.koboldt@dotecon.com / dan.maldoom@dotecon.com.

DotEcon was engaged by Radio Spectrum International (RSI) to assist with the design and implementation of an allocation process for 3.5GHz spectrum in Nigeria. RSI was responsible for managing the allocation process on behalf of the Nigerian Communications Commission, the independent regulator that undertakes telecommunication licensing in Nigeria.

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1 Introduction

Fixed wireless access (FWA) is the use of radio technology to provide the so-called 'last mile' connection between users and the core telecommunications network. It can be used for delivering both voice telephony and data services with typical speeds of 64Kbps to 2Mbps. FWA services can provide a more cost effective access solution than copper-pair exchange lines where these are absent and users sparsely populated. In many cases, wireless access technologies are capable of being deployed much more rapidly than wireline technology. These attributes are particularly attractive in emerging economies, such as Nigeria, where economic development has arguably been frustrated by the failure of state-run telecoms monopolies to develop adequate fixed line infrastructure.

In Nigeria, Africa's largest nation with a population of over 125 million, there are only around 400,000 wireline telephones in service, implying a teledensity of under 0.4%.[1] The huge latent demand for telecommunication services is demonstrated by the success of Nigeria's first two private GSM operators – Econet and MTN – which commenced commercial services in August 2001. In their first year, the two operators achieved a combined subscriber base of over 1 million.[2]

In March 2001, following its success in licensing the new mobile operators, the Nigerian Communications Commission[3] (NCC) identified FWA licensing as its next priority in terms of expanding private sector provision of telecom services. In particular, it recognised the potential of FWA services to contribute to the development of Nigerian telecoms provision in two key areas:

- **Internet access.** Facilitated by an open political environment and the use of English as an official national language, the Internet has grown rapidly in popularity in Nigeria. As elsewhere in English-speaking sub-Saharan Africa, the most visible sign of this is the surge in the number of ISPs and

[1] International Finance Corporation, Project no. 11206 (MTH Nigeria), from http://www.ifc.org/.

[2] 'Pleasure and Pain in One Year of GSM Operation', Media Rights Agenda, Sept 2002, http://www.internews.org/mra/MRM/sep02/sep02_story4.htm

[3] The independent regulator responsible for allocating telecoms licences in Nigeria. DotEcon and RSI advised the NCC on the allocation of FWA licences.

Cybercafes operating in the major cities.[4] However, dial-up access to the Internet in Nigeria is often frustrated by the poor quality of the incumbent operator NITEL's fixed line network. To the extent that FWA services will enable users to bypass bottlenecks in NITEL's local access network, the technology offers the potential significantly to expand domestic data traffic.

- **Regional roll-out.** Many regions in Nigeria are very poorly served by NITEL, even though there may be sufficient demand to justify commercial services. There is no imminent prospect of NITEL significantly improving its fixed line services in these regions. Meanwhile, the new GSM operators are focused on roll-out in the major urban areas, and will only turn to the more marginal regions when this is complete.[5] FWA services could potentially plug this hole in telecoms provision, as they could be rolled out for small non-contiguous areas and (unlike mobile telephony) do not require extensive coverage, provided that there is interconnection with backbone networks.

The NCC identified two frequency bands which were suitable for the provision of FWA licences: 3.5GHz and 10GHz. It decided (for the time being) only to offer licences in the 3.5GHz band and to limit the number of licences to two or three in each region. This reflected the perceived cost advantages of 3.5GHz, owing to the ready availability of standardised equipment, as well as uncertainty about the number of providers that could be sustained. For policy reasons, the NCC decided that FWA licences would be issued separately in 37 regions: the 36 Nigerian States plus the Federal Capital Territory of Abuja. Each licence was endowed with a block of 2x14MHz of spectrum.

The allocation process took place over nine months, from October 2001 to June 2002, with successful bids totalling 3.78 billion naira (37.8 million US dollars). Designing the overall process and, in particular, the auction stage, posed unique challenges. Like the Nigerian GSM auction, the design and implementation of the allocation process was guided by a combination of economic theory and significant practical constraints. However, the choices were

[4] See, for example: Hiawatha Bray, 7/23/2001, 'Entering the queue – At Africa's no-frills cybercafes, thousands are flocking to get online', Boston Globe (www.boston.com/globe/nation/packages/wiring_africa/part2.htm).

[5] For example, as of May 2002, Econet offered services in ten cities, with plans to launch services in a further three (http://www.econet-nigeria.com/).

more complex owing to the very large number of licences[6] and the uncertain but potentially large number of bidders. Overall, the exercise provides a useful case study of the compromises that are required in auction design in order to deliver practical solutions for complex allocation problems in developing countries.

In this paper, we analyse the design, implementation and outcome of the allocation process, in particular focusing on the motivations for adopting a single round, sealed bid combinatorial auction format. Although this was the first time that combinatorial bidding had been used for allocating spectrum licences, such formats have received increasing prominence in recent years. Ausubel and Milgrom (2002) observe "*growing interest in allowing bidders much greater flexibility to name the packages on which they bid.*"[7] Most prominently, the US Federal Communications Commission (FCC) plans to use an ascending combinatorial (package bidding) format for the auction of spectrum in the Upper 700MHz band.[8] Combinatorial auctions have also been held for real estate and for allocating bus route franchises to private operators[9].

In Sections 2 and 3, we discuss the NCC's objectives and other constraints imposed on the design and implementation of the allocation process. In Section 4, we describe the four-stage allocation process that was adopted. Section 5 provides a description and analysis of the auction outcome. In Section 6, we conclude that the sealed bid combinatorial auction is most likely to have application where there are strong synergies between lots *and* either (a) competition is weak or collusion a concern or (b) it is impractical or not cost effective to run a multi-round auction.

2 The NCC's objectives

At the start of the project, the NCC communicated three main objectives for the allocation process:

[6] In total, there were 80 licences available to applicants: three each in the six largest regions, and two in the other 31 regions.

[7] Ausubel and Milgrom (2002), p2.

[8] This auction was been repeatedly rescheduled. As of May 2003, there was no scheduled start date. See http://wireless.fcc.gov/auctions/31/ for details of the auction design.

[9] London Transport has used a sealed bid combinatorial auction format for licensing bus route operators. See Cantillon and Pesendorfer (2002) for details.

1. **Transparency.** Nigeria has only recently completed the transition from a military dictatorship to open, multi-party democracy. The previous regime was highly corrupt and there remains a high level of cynicism within the business community about the motivations of government bodies responsible for allocating licences and permits.[10] In order to maintain and develop its institutional legitimacy, it was extremely important to the NCC that any allocation process be transparent and the outcome be perceived as fair.
2. **Efficiency.** The ultimate objective of the allocation process was to support the development of the Nigerian economy through the expansion of telecommunication services. Therefore, licences should be allocated to those companies that will use them most effectively.
3. **Regional services.** The NCC wished to encourage the roll-out of FWA services in as many areas of the country as possible. This was the primary motivation for allocating the licences on a state-by-state basis. There was concern that if licences were sold on a national or multi-regional basis, they might be acquired by bidders who would focus roll-out on a few key urban areas, while neglecting more marginal economic areas. There was also political pressure on the NCC from some state governments anxious to ensure that small bidders focusing on single states were not excluded from the process.

As the market potential for FWA services in different areas of Nigeria varied widely, it was decided to divide the licensing regions into five tiers for the purposes of setting reserve prices and roll-out obligations. Licences in the less attractive regions had lower prices and less challenging conditions. The NCC also restricted the number of licences available in the 31 regions in the three lowest tiers to two, owing to concerns that these markets might not be able to sustain three competitors.

From the outset, the requirements for transparency and efficiency led the NCC strongly to favour an auction process. A beauty contest was considered undesirable owing to the difficulty of developing objective criteria for accessing applications and the risk that losing bidders would allege that the process was biased or, worse, corrupt. By contrast, with an auction, it is possible to distinguish between bidders on the basis of a single objective criteria, i.e. the amount

[10] Nigeria ranked 101st out of 102 countries in Transparency International's 2002 survey of perceptions of corruption. The survey relates to perceptions of the degree of corruption as seen by business people, academics and risk analysts. See http://www.transparency.org/cpi/

they are willing to pay. Moreover, provided that the process is well designed, market power absent and bidders behave rationally, those willing to pay the most for licences should also be those with the best business cases to develop FWA services.

The NCC already had a positive experience of using an auction to allocate spectrum licences. In January 2001, it allocated three national licences to provide GSM mobile phone services using an ascending clock auction.[11] The auction, which lasted for 17 rounds over three days, raised 285 million US dollars per licence. The process drew praise from local and international observers. Its perceived success contrasts sharply with the failure of a previous effort to sell the same licences by comparative selection in early 2000; that process was cancelled, "after doubts were raised about the integrity of the process."[12]

3 Constraints on the design of the allocation process

There are many examples of governments running auctions for large numbers of spectrum licences across multiple regions. These include the Austrian, Canadian, Swiss and UK FWA auctions, and Australian, Canadian and US 3G/PCS auctions. Table 1 contrasts the number of regions and licences in selected spectrum auctions with the structure of FWA licences in Nigeria. In this regard, there was nothing particularly remarkable about the ambitions of the NCC. However, spectrum auctions of this magnitude, in terms of regions and lots, are still comparatively rare in developing economies.[13]

Most spectrum auctions for lots in multiple regions have used a simultaneous multiple-round auction (SMRA) format, based on the

[11] This auction was also organised by RSI. For a detailed description of the auction process, see: Doyle and McShane (2001).

[12] Ibid, p5.

[13] Amongst developing countries, spectrum auctions have been most prevalent in Latin America, whose regulators have been influenced by the experiences of the US FCC and Guatemala's Superintendencia de Telecomunicaciones (SIT), both global pioneers in the deployment of market mechanisms and property rights in spectrum management (see http://www.sit.gob.gt/ for details about SIT's approach). Elsewhere, one of the first developing countries to use spectrum auctions was India, which sold regional GSM and basic service licences in the mid-1990s, but this process had mixed success owing to deficiencies in the auction rules and regulatory framework, insufficient demand and bidder default [for a description of India's spectrum auction experience, see Jain (2001) and Jain (2002)].

procedures pioneered by the US FCC in the 1990s. In an SMRA, all licences are sold at the same time, with bidders invited to make ascending bids over multiple rounds, until prices reach an equilibrium level where demand for all licences does not exceed supply. Amongst the auctions listed in Table 1 (Nigeria excluded), only Switzerland did not use an SMRA; instead choosing to sell the licences sequentially by ascending bid.

Table 1: Examples of multi-region spectrum auctions

Auction	Date	No. of lots	No. of regions	Lots per region
US PCS	Mar 1999	356	345	1 or 2
Canada 24 & 38 GHz	Oct 1999	354	59	6
Swiss WLL 3.4 & 26 GHz	Mar 2000	48†	9	5
Austria WLL 36 GHz	Nov 2000	30	6	5
UK BFWA 28 GHz	Nov 2000	42	14	3
US PCS (C&F)	Dec 2000	422	195	various
Canada PCS	Jan 2001	62	14	4-6
Australia 3G	Mar 2001	58	18	Various
Nigeria FWA	May 2002	80‡	37	2 or 3

†including 3 national licences; ‡Only 50 of the 80 available licences were included in the auction; Source: http://www.dotecon.com/auctions/spectrum/recent.htm

In assessing the suitability of these standard auction models for the FWA allocation process in Nigeria, the design team were faced with two significant constraints:

1. *Lack of information on the level and structure of demand*

   At the onset of the process, there was a very high level of uncertainty about the potential level of demand from operators to run FWA services. The NCC had held a workshop for interested parties in April 2001 and had received a number of enquiries from potential bidders, but was very uncertain as to whether this would translate into actual licence applications.

   The international context at the time could hardly have been less promising: financial market sentiment towards telecom operators was at a low ebb and many of the companies that had pioneered

wireless local loop services in Europe were going bankrupt. The most high profile recent FWA sale – the UK BFWA auction in November 2000 – had disappointed, with many applicants failing to bid and a large number of licences going unsold.[14] However, it was unclear if this negative background would affect demand for FWA services in Nigeria, as the local context is very different to Europe and North America. In particular, whereas European WLL operators need to win data traffic from established fixed line competitors, FWA operators in many parts of Nigeria would be developing virgin markets.

The design team was also concerned about the extent of synergies between licences in different regions. It was anticipated that some applicants would apply for spectrum in multiple regions, in the hope of reaping economies of scale, for example in relation to carriage of backhaul traffic, equipment purchase and marketing. However, beyond the obvious economic linkages between certain adjoining regions, no information was available about the type of aggregations bidders might pursue. In addition, it was considered likely that some bidders would be cash constrained, and therefore would consider a number of different regions as alternatives.

Complementarity and substitutability between licences are important because if bidders are unable to express these relationships in their bids, an inefficient allocation may result. Sequential auctions have particularly poor efficiency properties in this regard, as bidders must bid for one lot without knowing the likely price of a later substitute or complement. As a result, bidders may win the 'wrong' licence at prevailing prices or be 'stranded' with a licence they do not want because a complementary licence was too expensive. Bidders, of course, are often aware of these risks, and will tend to respond by bidding more conservatively. This, in turn, may lead to inefficiencies, for example disfavouring bidders trying to aggregate a number of regions relative to those seeking single licences.

An SMRA is effective in mitigating substitution risks, as bidders can switch between licences on the basis of relative prices. This format also reduces aggregation risks to the extent that bidders can monitor their likelihood of winning complementary licences and respond appropriately as prices rise. However, with an

[14] Details of the rules and results for the 2000 UK auction of BFWA licences can be found on the UK Radiocommunication Agency's website at http://www.spectrumauctions.gov.uk/bfwa/bfwa_index.htm.

SMRA, there remains a risk that bidders may be stranded on unwanted licences if the price of a complementary licence rises unexpectedly. The problem of aggregation risks is most effectively resolved by allowing bids using a combinatorial auction format.[15] This allows bidders to make bids for combinations of licences, which are accepted or rejected in their entirety. Consequently, bidders can avoid being stranded with unwanted licences.

2. *Logistical constraints*

   The auctions described in Table 1 (Nigeria excluded) were run with remote bidding over the Internet or via private networks accessed by dial-up connections. Ideally, the design team would have liked to use similar technology in Nigeria. However, it was concluded that the communication and power infrastructure in Nigeria was insufficiently reliable to run an auction in this way.

   A similar dilemma was faced by the design team for the Nigerian GSM auction.[16] Their solution was to hold the auction at a single location with all bidders present. This was also an option for the FWA process. However, while co-location works well with a small number of bidders (five in the case of the GSM auction), it can become prohibitively expensive with large numbers. With FWA spectrum, the cost of the allocation process was potentially an important consideration, as the level of revenues was uncertain and potentially quite small, and the NCC was concerned that smaller bidders (especially those competing for the more remote regions) should not be discouraged from participating.

   The NCC was also keen that the auction stage should be completed as quickly as possible, subject to not undermining its primary goals of efficiency and transparency. It did not wish to expose itself or bidders to the expense of a lengthy auction, especially given the impracticality of running the process remotely.

   In his discussion of sealed bid and ascending auctions, Cramton (1998) points out that, "*one of the traditional reasons for sealed bidding is that … it may be too costly to get [bidders] all together for an ascending bid auction*". He goes on to state that: "*This reason is now irrelevant. Today, communication technologies have advanced to the point where bidders can easily participate*

[15] For a good overview of combinatorial auctions, especially in relation to ascending bidding, see Ausubel and Milgrom (2002), and Charles River Associates and Market Design Inc. (1997).

[16] Doyle and McShane (2001).

in ascending auctions without leaving the comfort of their homes. The Internet is used to conduct hundreds of ascending auctions each day with bidders worldwide. Security and reliability issues largely have been solved."[17] However, while this is true for developed countries, it is not the case in Nigeria. Notwithstanding developments such as FWA licensing, deficient infrastructure is likely to remain a dominant factor in auction design in many developing countries for years to come.

In light of these constraints, the design team concluded that it would be helpful to understand the extent of competition and demand interrelationships in order to refine the process. Without such information, it would be impossible to assess with confidence whether certain regions would even be contested and, if so, what auction format would be appropriate. More specifically, the feasibility of adopting a multiple-round format and co-locating bidders hinged on the number of regions that were contested (and thus needed to be included in an auction) and the number of bidders competing for them. The feasibility of using a sealed bid depended on whether this would be grossly inefficient in light of the extent of demand interrelationships between regions.

The design team was also mindful of the experience of European 3G auctions, many of which were perceived to have 'failed' when licences sold for low prices as a result of weak demand. Klemperer (2002b) attributes the problems of the Dutch and Swiss 3G contests, in particular, to a lack of appreciation of the role of auction design in creating incentives for entry and discouraging collusion.[18]

These concerns led directly to the choice of a four-stage allocation process, which we describe below. The purpose of the first two stages was to obtain and evaluate information about the level and structure of potential demand in order to determine if an auction was required and the appropriate format. The information received significantly enhanced the NCC's understanding of the market for FWA licences and was fundamental to the decision to adopt a sealed-bid combinatorial auction format.

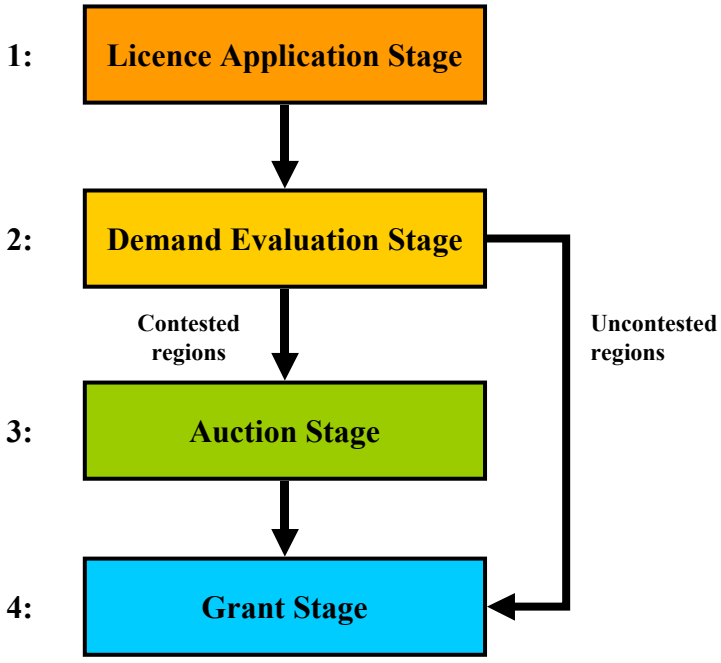
[17] Cramton (1998).

[18] Klemperer, P (2002b)

4 The four-stage allocation process

The FWA allocation process consisted of four stages: a licence application stage; demand evaluation stage; auction stage; and grant stage. The primary purpose of the first two stages was to assess the level and structure of demand for licences on a region-by-region basis, in order to develop an appropriate auction design. We illustrate this process in Figure 1. Below we describe the four stages in detail.

Figure 1: The four-stage licence allocation process for FWA spectrum



4.1 The licence application stage

At the licence application stage, bidders were invited to submit their demands for licences across all regions at the reserve prices. The applications were both binding (where demand did not exceed supply, bidders would be committed to purchase at that price) and constraining (if bidders did not bid apply for a particular region, they would not be allowed to bid for it later). These conditions were essential in order to give bidders incentives to reveal their preferences for licences. We review the effectiveness of these conditions in Section 5 below.

In '*uncontested regions*', where demand was equal to or below supply, licences would be allocated to successful bidders at the reserve price. '*Contested regions*', where demand exceeded supply, would be included in a subsequent auction stage. In the unlikely event that no region had excess demand, all licences would have been allocated, and there would have been no need for an auction.

The purpose of the reserve price was to recover the costs of the allocation process and to deter frivolous applications. The reserve prices varied depending on the size of the regions and were set at a low (but non-trivial) level, as the NCC did not want to discourage applicants. This stage also served as a qualification stage; applicants that failed to submit adequate deposits or commit to basic technical conditions of the licences were eliminated.

In designing the application form, an early concern was that bidders who considered certain regions to be complements or were budget constrained might be disadvantaged. A simple application form that asked bidders to respond 'yes' or 'no' to a licence in a particular region would leave bidders exposed to substitution and aggregation risks. For example, in the absence of any information about the level of competition for licences, a budget-constrained bidder who wanted either Region A or Region B but not both would face a dilemma about which region to bid for. Meanwhile, a bidder pursuing a combination of regions would risk winning some of the regions it wanted but find that other complementary regions were contested and would proceed to auction, where prices could rise beyond its business case.

In order to alleviate these risks for bidders, the application form had two special features:

- Bidders were given the opportunity to make up to five separate, mutually exclusive, combinatorial bids. Each bid at the application stage consisted of an application for licences in one or more regions. The purpose of allowing multiple bids was to enable bidders to indicate combinations of regions that they considered to be substitutes at the reserve price levels. A limit of five bids was set in order to ensure that the subsequent demand evaluation stage was not excessively complicated and to keep the process simple for bidders.
- Bidders were also able to designate individual licensing regions as 'critical' or 'non-critical' in a particular combinatorial bid. A region is 'critical' if the bidder's demand for other regions in the same bid is contingent on winning a licence in that region. A region is 'non-critical' if failure to win a licence in that region would not affect the bidder's requirement for licences in other regions in the same bid. In the event that any regions that were marked critical proceeded to the auction stage and the bidder failed to win them, these bidders would be given the

option to withdraw from licences in any uncontested regions awarded as part of the same bid. By allowing bidders to link demand for licences in different regions in this way, they could largely eliminate aggregation risks.

4.2 Demand evaluation stage

Applications were examined in order to establish whether there was a combination of bids (one for each bidder) that cleared the market. Such a combination would require that at least one bid (i.e. for one or more regions) from each bidder was satisfied and that these bids in aggregate would not result in excess demand for licences in any region. Had such a combination existed, then no auction stage would have been required and the allocation process would have moved directly to the grant stage.

The test for a market clearing solution was performed using bespoke software, owing to the complexity of matching up bids across bidders where bidders had made multiple exclusive bids. However, in practice, the level of demand for some regions was so high that it was immediately obvious that no market clearing solution would exist.

In the absence of a market clearing solution across all regions, it was necessary to analyse the level of demand on a regional level. By calculating the highest potential level of aggregate demand by region (taking at most one bid per bidder), it was a simple task to determine where demand for licences potentially exceeded supply (under any combination of bids), thereby determining which regions needed to be included in an auction.

4.3 The auction stage

4.3.1 Auction design options

The information revealed in the application and demand evaluation stages played a critical role in influencing the choice of a sealed bid combinatorial format for the auction stage. An early conclusion was that, with a large number of bidders, it would not be possible to run a multi-round auction. An Internet or fax-based multi-round process had already been rejected as infeasible, owing to deficient infrastructure. Two options for multi-round auctions with bidders co-located were briefly considered: running an SMRA for all contested regions; or running a series of sequential multiple-round auctions, one for each region, which would have reduced the maximum number of bidders in any one auction. However, these were also rejected, owing to the prohibitive cost of co-locating large numbers of bidders for an uncertain length of time and, in the second case, because of potential for grossly inefficient outcomes.

Having ruled out a multi-round auction, the design team focused on options for a single-round sealed-bid process. Such auctions are simple, quick and inexpensive to implement, and are less vulnerable to collusion between bidders than multiple-round processes.[19] However, (in the absence of collusion) they typically produce less efficient outcomes than multi-round contests, as bidders must submit their bids without any opportunity to learn from the behaviour of their competitors.[20] The NCC took the view that this loss of efficiency was within acceptable bounds in the local context.

A further concern with using a sealed bid process was the particular difficulties that would be faced by bidders seeking to acquire combinations of licences across regions, especially where there are strong synergies between the licences. Analysis of the results from the demand evaluation stage suggested that these synergies were often significant, and that many bidders valued combinations of regional licences more highly than the sum of their individual values.

This problem could have been partially mitigated by auctioning the licences sequentially rather than at the same time. This would have given bidders the opportunity to learn from previous auctions as the process went on. However, bidders would still have faced the risk of having to bid for one licence without knowing their prospects of winning a later auction for a complementary licence. A more effective solution is to allow bidders to make bids for combinations of licences as well as individual licences.

Unlike a standard auction, bidders in a combinatorial auction can submit multiple bids, one for each combination of licences that they are eligible to acquire. Put differently, bidders can submit bids for both individual licences and for combinations of licences, and vary the amounts they bid to reflect any complementarities. The use of combinatorial auctions has recently been championed by the US FCC, although it has not yet run an actual auction using this format:

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[19] In auctions where participants are pursuing aggregations of regional licences, there may be significant opportunities for bidders to collude to the detriment of other bidders. Using a single-round, sealed bid rather than multi-round process reduces opportunities for collusion and also makes it difficult for colluding parties to enforce deals between themselves (bidders may have an incentive to 'cheat' on a partner in the knowledge that they will not be found out until after the event). Of course, making bidders sign up to robust anti-collusion clauses should also discourage collusion, but there were doubts as to whether such measures were enforceable in practice in Nigeria.

[20] For a discussion of the relative merits of sealed bid and ascending auctions with common values, and the role of information in influencing bidder behaviour, see Cramton (1998).

> *"In general, [combinatorial] bidding should be an improvement over our usual auction design when (a) there are strong complementarities among licences for some bidders, and (2) the pattern of those complementarities varies for different bidders. Under these circumstances, [combinatorial] bidding should yield the more efficient outcome, with licences being sold to those bidders who value them most."*[21]

The Nigerian applications featured very varied combinations of licences and produced strong evidence of complementarities between FWA Licences that differed across bidders. From this, it was apparent that there were potentially strong efficiency benefits from using a combinatorial format. Moreover, allowing bidders to submit multiple but exclusive bids could mitigate some of the potential efficiency losses from using a sealed bid rather than multi-round format.[22] The design team therefore recommended that the NCC adopt a sealed bid process with combinatorial bidding, subject to additional rules to ensure that the process would be reasonably simple and transparent for bidders and observers.

4.3.2 The sealed-bid combinatorial auction

The key features and rules of the auction were as follows:

Pre-auction information

Following the conclusion of the demand evaluation stage, the NCC published a list of all applicants for FWA spectrum and details of all the regions that they had applied for. This information was released to enable bidders to assess the potential level of competition in each region, thereby mitigating some of difficulties associated with using a single rather than multi-round format.

Auction groups and sequencing

Permitting combinatorial bidding adds significant complexity to the standard sealed bid auction. The ability of bidders – typically small local operators – to comprehend the process was therefore a significant concern. In theory, efficiency gains would be maximised by auctioning all contested regions in the same combinatorial auction. However, this would mean that bidders would face a large number of possible combinations (the number of combinations grows

[21] Public Notice DA 00-1486, US Federal Communications Commission, July 3, 2000.

[22] Efficiency might be further increased by using a hybrid combinatorial SMRA, as planned by the FCC. However, this was not a practical option in Nigeria, for reasons already outlined.

exponentially with the number of regions). Furthermore, although computer software could be used to process such a result, it was important that the final outcome be transparent and robust to criticism.

It was therefore decided to allocate licences in the contested regions through five separate sealed bid combinatorial auctions, each one including four or five regions. This reduced complexity for bidders and made processing of results easier and verifiable by third parties (without the necessity to use sophisticated winner determination algorithms). Although not a first-best solution, it was judged that the benefits of simplicity and transparency from running five auctions rather than one big auction outweighed the loss in efficiency which would result from preventing bidders from making bids for some combinations of regions.

The decision to opt for five auctions was facilitated by information on the structure of demand from the first stage of the process. This revealed that nearly all bidders who were pursuing combinations of regions were either focused on specific parts of the country (e.g. South-west Nigeria or Northern Nigeria) or the four largest regions (Abuja, Delta, Lagos and Rivers). Therefore, the efficiency loss from breaking up the regions into groups could be minimised by structuring the groups to ensure that regions that were often demanded in combination were in the same auction.

In addition, many bidders had also indicated that their demand for licences in smaller regions was contingent on winning licences in one or more of Abuja, Delta, Lagos and Rivers. It was therefore decided to auction these regions first, to be followed by regional groupings. Holding the auctions in sequence gave bidders time to adjust their bids in later auctions in light of the outcome of earlier ones, thereby reducing aggregation risks relative to holding separate auctions in parallel.

The bid forms

For each auction, bidders were provided with a single, tailored bid form. The bid form listed all possible combinations of regions that a specific bidder was eligible to bid for within the auction:

- with four regions, each bidder has up to 15 possible combinations.
- with five regions, each bidder has up to 31 possible combinations.

However, bidders were only permitted to bid for combinations of regions consistent with their initial applications. For example, in Auction 1:

- a bidder whose initial application included Delta, Lagos, Rivers and Abuja could submit up to 15 bids; whereas

- a bidder who applied for only Delta and Lagos could only make up to 3 bids (i.e. Delta; Lagos; and/or Delta & Lagos).

Table 2 illustrates all the possible bid combinations for Auction 1. Tailoring bid forms so that they only included the bid combinations that specific bidders were eligible for was instrumental in helping bidders to understand the process and minimise the risk of mistakes.

Table 2: Possible Bid Combinations for Auction 1

Combinations		Reserve price (naira)
1	Delta	16,800,000
2	Lagos	28,000,000
3	Rivers	16,800,000
4	Abuja	16,800,000
5	Delta & Lagos	44,800,000
6	Delta & Rivers	33,600,000
7	Delta & Abuja	33,600,000
8	Lagos & Rivers	44,800,000
9	Lagos & Abuja	44,800,000
10	Rivers & Abuja	33,600,000
11	Delta, Lagos & Rivers	61,600,000
12	Delta, Lagos & Abuja	61,600,000
13	Delta, Rivers & Abuja	50,400,000
14	Lagos, Rivers & Abuja	61,600,000
15	Delta, Lagos, Rivers & Abuja	78,400,000

Bidders were invited to submit a bid amount for each combination that they are prepared to purchase. All bids were in whole naira. Each bid was 'mutually exclusive', i.e. no more than one of the combinations bid for by any particular bidder could be accepted in the final allocation of licences.

Reserve prices and minimum bids

The initial minimum bid level for individual licences were set at the same level as the reserve prices in the initial applications. The minimum bids for each combination was set as the sum of the reserve prices (see Table 2).

Winning bids

Bidders were allocated licences by choosing the set of bids in each auction that had the highest total value, subject to (a) choosing at most one successful bid for each bidder and (b) the total number of licences allocated not exceeding the number available within each region. This procedure is the direct equivalent of accepting the

highest bids in a simple sealed-bid auction, and represents the most efficient outcome.

A computer algorithm was used to process all the bids received. For each auction, the program searched for the set of bids that produced the highest total value. There were also some simple rules for addressing tie breaks[23], but these were not required.

Licence fees

The successful bidders paid the amount that they bid for the relevant combination of licences in each auction. There was discussion with the NCC about the possibility of calculating a marginal price for each region, such that all successful bidders would have paid similar amounts for the same regional licences. However, this was rejected owing to the complexity and potential lack of transparency in calculating a marginal price with combinatorial bids.

4.3.3 The auction logistics

The logistics required to facilitate the auctions were relatively straight-forward. The entire process was run from the head office of the NCC in Abuja. An auction control team, made up of the advisors appointed by the NCC and the NCC's representatives, was set up to administer the process.

Authorised persons

Upon publication of the auction rules, bidders were asked to nominate up to two authorised persons to attend the bidder seminars, and to collect and submit the bid forms. These authorised persons were required to have legal authority to submit binding bids.

Bidder seminars and registration

Prior to commencing the auctions, the NCC ran a number of 'bidder seminars' outlining the auction rules and procedures, followed by a question and answer session. The seminars played a key role in familiarising bidders with the concept of combinatorial bidding.

The seminar sessions were also used as an opportunity to register the authorised persons, and to issue them with their individual bid forms for the five auctions.

[23] In the unlikely event that there had been more than one set of bids that generated the same highest total value, then the tie-break would have been resolved in the following way: (1) the set of bids that resulted in the allocation of most licences would have been selected; (2) if there was still a tie, then the set of bids that resulted in the allocation of licences to the most bidders would have been selected; (3) if there was still a tie, a random process would have been used to select the winning set of bids.

Submission of bids

On the day of each auction, bidders submitted a sealed envelope containing the appropriate bid form to the designated point at the NCC's headquarters. The sealed envelopes were received by an NCC representative, who registered their arrival and then delivered them to the auction control team. Envelopes which were not sealed or were delivered outside the specified time window were not accepted.

Opening and processing of bids

Once the deadline for bids in an auction had passed, the auction control team opened all envelopes received in alphabetical order. A number of checks were performed to ensure that the bid forms were valid. In the Nigerian context, reassuring bidders that they would all be treated equally and that there would be no possibility of bids being changed after submission was of paramount importance. There were strict rules for dealing with invalid bids. Moreover, bidders were warned in advance that there would be no opportunity for them to correct 'mistakes'. Authorised representatives of all bidders were invited to observe the entire process of opening the envelopes and determining the successful bids.

Notification of results

The processing and validation of the results for each auction took around 1-2 hours. The results were announced immediately to all authorised persons who had observed the process and published on a notice board at the NCC headquarters and on the NCC website (www.ncc.gov.ng).

In order to demonstrate the transparency of the process, full information about the bids submitted by all bidders was released, namely:

- by bidder, a list of all licences awarded;
- by region, a list of all bidders awarded licences; and
- by bidder, details of all bids submitted in the auction, including both successful and unsuccessful bids.

4.4 The grant stage

Successful bidders in the auction and application stages proceeded to a grant stage. Each successful bidder was given 21 days to pay the amount of their winning bids. Upon payment, the bidders were allocated 15-year licences for specific frequency bands. In the event that bidders defaulted on payment, there were procedures for reallocating defaulted licences to the next highest unsuccessful bidders in the auction.

Bidders who had applied for spectrum in uncontested regions but were not obliged to take this up because they had failed to win

licences in critical regions, were offered these licences at the reserve prices. They had 7 days to decide whether they wanted the licences and a further 21 days to pay for them.

5 The outcome

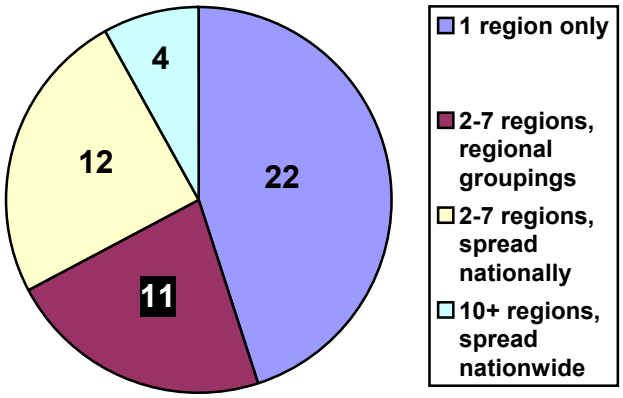
5.1 Outcome of the demand evaluation stage

Initial concern that there might be relatively little demand for FWA spectrum outside a few major regions proved unfounded. The NCC received 49 eligible applications for FWA spectrum. Some 22 of the 37 regions were contested (i.e. there was potential excess demand for FWA licences). The remaining 15 regions were uncontested (i.e. potential demand for licences was less than or equal to supply). Only one bidder had applied solely for spectrum in uncontested regions. The other 48 bidders all applied for licences in contested regions and thus had to be accommodated in an auction.

In addition to providing data about the level of demand by region, the applications revealed useful information about the structure of bidders' demands. Bidders applied for a large variety of combinations of regions (see Figure 2):

- 22 bidders applied for licences in one region only.
- 23 bidders applied for between two and seven regions. Amongst these, eleven applied for spectrum in adjoining regions. The remaining twelve applied for spectrum in regions spread nationally (typically but not exclusively the higher tier regions).
- Four bidders applied for spectrum in ten or more regions, spread across the whole of Nigeria. One of these bidders applied for spectrum in all regions.

Figure 2: Types of bids received in the Demand Evaluation Stage



Demand was focused particularly on four major regions: Lagos (19 bidders), Rivers (18 bidders), Abuja (15 bidders) and Delta (13 bidders). These four regions also received a very high proportion of 'critical' bids, indicating that much of the demand for spectrum elsewhere was dependent on bidders winning spectrum in these regions. Other regions with high levels of demand were Oyo (11 bidders), Anambra (11 bidders), Ogun (10 bidders), Edo (9 bidders) and Kano (8 bidders). These regions were sometimes marked as critical, typically as part of a bid focusing on a particular geographic area of Nigeria.

Although demand exceeded supply of licenses in many smaller regions, it was still uncertain whether all the licenses would be sold in these areas. This was because many bidders had linked their demand for these regions to success in other, larger regions. Amongst the 15 uncontested regions, there were eleven where only one bidder (UBA Capital & Trust Ltd) had applied for spectrum, and its commitment to taking up these regions was potentially dependent on winning spectrum in its critical regions of Lagos, Rivers and Abuja.

5.2 Selection of auction groups and sequencing

Based on the information obtained in the demand evaluation stage, it was decided to hold five separate auctions (see Table 3). The auction groups were structured as follows:

- The first auction included licences in the four regions where demand was highest: Lagos, Rivers, Delta and Abuja.
- The other four auctions grouped regions that are in close geographical proximity. This reflects the fact that there was a relatively high degree of demand overlap for adjoining regions, whereas demand overlap for regions in different parts of Nigeria was comparatively rare.

Table 3: Auction Groups

Auction	Regions
Auction 1	'Critical' regions:
	Delta, Lagos, Rivers, Abuja
Auction 2	South-west Nigeria:
	Edo, Ogun, Ondo, Oyo
Auction 3	Southern Nigeria:
	Abia, Akwa Ibom, Bayelsa, Cross River, Imo
Auction 4	North / Central Nigeria:
	Gombe, Kaduna, Kano, Nassarawa, Plateau
Auction 5	South / Central Nigeria
	Anambra, Benue, Ebonyi, Enugu

The five auctions took place in three steps:

- Auction 1 was held first.
- Auctions 2 and 3 took place after the completion of Auction 1. They were separate auctions but took place in parallel.
- Auctions 4 and 5 took place after the completion of Auctions 2 and 3. They were also separate auctions but took place in parallel.

This sequencing was designed to reduce the impact of synergies between auctions. By holding Auction 1 first, bidders for synergistic regions in later auctions would not be exposed to aggregation risks related to uncertainty over whether they would win 'critical' licences in Abuja, Delta, Lagos and/or Rivers. Full results from Auction 1 were announced before the start of Auctions 2 and 3, so as to allow bidders time to adjust their bids in later auctions accordingly. Similarly, full results from Auctions 2 and 3 were made available before the start of Auctions 4 and 5.

It was decided to run Auctions 2 and 3 at the same time, as there was relatively little demand overlap across the two groups. The same decision was made with regard to Auctions 4 and 5. By scheduling the auctions in this way, the NCC was able to speed up the overall process for bidders, with little risk to the efficiency of the final outcome.

5.3 The auction outcome

Some 48 of the 50 licences available in contested regions were allocated in the five auctions for a combined 3.59 billion naira (36 million US dollars). A further 19 of the 30 licences in uncontested regions were allocated at the reserve prices, based on the initial applications, raising an additional 184 million naira. The combined total was 3.78 billion naira. Only 13 of the 80 licences went unsold, and at least one licence was allocated in every region. This fulfilled the most optimistic projections of the NCC and attracted very positive coverage in the local press.

Unfortunately, five of the 25 successful bidders defaulted after the auction. Most of their licences were reallocated to other bidders on the basis of the next highest unsuccessful bids in the auctions. Nevertheless, the defaults resulted in a significant reduction in total revenues, as the defaulters included the three bidders with highest aggregate successful bids.

The high level of demand for licences observed at the application stage was translated into a high level of bid activity across the five auctions. Table 4 provides some summary statistics on activity. In total, 45 of the 48 eligible bidders participated in one or more of the auctions. Bidders made significant use of the opportunity to make multiple bids, including combinatorial bids. Actual bids across all the auctions amounted to 59% of the maximum number of bids that active bidders could have made. Furthermore, some 40% of actual bids were combinatorial (i.e. for licences in more than one region).

Table 4: Summary of activity in the five auctions

	Auction 1	Auction 2	Auction 3	Auction 4	Auction 5	All auctions
No. of regions	4	4	5	5	4	22
No. of licences available	12	8	10	12	8	50
No. of licences sold	12	8	10	10	8	48
No. of eligible bidders	30	18	11	13	17	48
No. of actual bidders	29	16	9	11	13	45
No. of potential bids*	151	74	72	39	39	375
No. of actual bids	105	50	21	22	24	222
Actual bids as % of potential bids*	70%	68%	29%	56%	62%	59%
No. of combinatorial bids	49	22	6	4	7	88
Combinatorial bids as % of actual bids	47%	44%	29%	18%	29%	40%
Total revenue raised (naira)	1.64bn	827mn	441mn	351mn	329mn	3.59bn

*Based on actual bidders only

5.4 Observations

5.4.1 Incentives for truth telling

The final choice of auction design rested heavily on information revealed about the regional structure of demand from initial applications. It was therefore critical that the application process created incentives for bidders to reveal such information. The decision to make the initial applications binding and tied to non-trivial deposits appears to have been effective in discouraging frivolous applications. Most bidders that passed the application stage participated in the auction, and the majority bid for all or most of the regions that they had initially applied for.

Bidders were also encouraged to reveal whether their demand for a particular region was potentially contingent on one or more other regions, by marking each one as critical or non-critical. This reduced bidder exposure to aggregation risks, while also revealing valuable

information about the nature of synergies between licences, which influenced the composition of the auction groups and their sequence. The usefulness of this information, however, depended on bidders being honest and not, for example, simply marking every region in a combinatorial bid as critical.

One possible weakness in the design of allocation process was that the incentives for bidders to reveal critical and non-critical regions truthfully were not as robust as they might have been. It should generally be in the interest of bidders pursuing licences in multiple regions to reveal such information to the auction designers, as this would increase the prospect that any final auction design would take into account their particular aggregation risks. Against this, bidders may perceive that they could gain an advantage over their competitors (or at least avoid a disadvantage) by hiding such information in advance of a possible auction. Although in practice there is no evidence in this case that bidders did seek to disguise their preferences by marking all regions critical, two additional steps might have served to mitigate this risk:

- additional deposits could have been required for regions marked critical; and
- the NCC could have announced in advance of the application stage (rather than afterwards as happened) that information about whether bidders had marked their initial bids for regions as critical or non-critical was considered confidential and would be not be publicly released.

5.4.2 Auction groups and sequencing

The structuring of the auction groups appears to have been reasonably successful. By grouping regions together that were in frequent demand by the same applicants, bidders were able to make bids contingent on winning those other regions with the strongest synergies. It is reasonable to suppose that a less efficient outcome may have occurred had multi-region bidders not been able to manage their aggregation risks in this way.

Several bidders suggested that had they known the composition of the auction groups before the application stage, they might have applied for more regions, so as to increase their bid options. However, this is a 'chicken and egg' situation. The decision to place regions in particular groups was based on the structure of demand revealed in the applications. Had bidders been allowed a second chance to apply for additional regions after the groups were determined, they would have had no incentive to be honest about their initial demand levels at the application stage. This, in turn, could have led to the loss of crucial information needed to structure the groups.

The decision to stagger the auctions, in order to allow bidders to adjust their bid strategy in light of early auction outcomes, was also effective. For example:

- Startech was successful in Auction 1 with a single bid for Abuja. This success gave it a platform to take part in Auction 4, where it made a successful combinatorial bid for licences in Kaduna, Kano, Nassarawa and Plateau. A representative of the company later revealed that it would not have had a business case to take part in Auction 4 had it not been successful with the Abuja bid.
- Dredew – eligible to participate in all four auctions – took no further part in the process after failing with a combinatorial bid for Delta, Lagos, Rivers and Abuja in Auction 1. It is likely that its business case for licences nationwide rested on having a platform in the four key regions.

Operating under the constraint that a simultaneous auction of all licences was not feasible, had the auctions not been staggered in this way, a less efficient outcome may have resulted. For example, with different sequencing, Startech and Dredew would have faced risks of being stranded with less important licences without one or more of the four major regions, which would have affected the amount that they were prepared to bid.

5.4.3 Aggregation and threshold risks

The primary motivation for adopting the combinatorial auction format was to reduce aggregation risk for bidders. By enabling bidders to express the value of synergies between regions in bids for combinations, the likelihood that licences will in aggregate be allocated to the bidders that value them most highly is increased.

Startech's success in auction 4 provides a good illustration of the efficiency benefits from using a combinatorial format. Startech apparently anticipated significant synergies from winning Nassarawa and Plateau in combination, either with or without Kaduna and Kano. It offered 39 million naira for Nassarawa and Plateau together but valued them in isolation at only 10 million and 14 million respectively. The combinatorial bid was successful, whereas only one of the two individual bids would have been sufficient to win a licence.

A number of bidders, such as Startech, took advantage of combinatorial bids to pursue licences in adjoining regions. The ability of bidders to combine bids for profitable regions with others with lower revenue potential almost certainly promoted the NCC's objective of spreading telecoms development as widely as possible. This outcome contrasts favourably with the auctions of GSM and basic service licences in India – another large country with multiple

regions, where applicants were forbidden from bidding for contiguous areas. It is likely that this rule significantly suppressed demand, as subsequent industry consolidation indicated a preference for contiguous regions.[24]

However, although combinatorial bidding reduces bidder 'exposure' to aggregation risks, it is not unambiguously beneficial, owing to the 'threshold' problem that potentially affects smaller bidders. In documentation on the US 700MHz auction, the FCC has defined the threshold problem as:

> "*the difficulty that multiple bidders for the single licences (or smaller packages) that constitute a large package may have in outbidding a single bidder on the larger package, even though the multiple bidders may value the sum of the parts more that single bidder values the whole.*"[25]

The significance of this problem and possible auction rules to counter it have been the source of significant debate between academic commentators on the 700MHz auction.[26] In a multi-round context, a particular concern is that bidders for parts of a larger package (i.e. group of licences) may have an incentive to hold back in the hope that a bidder for another part will increase its bid sufficiently for these bids collectively to beat the bid on the larger package. This incentive to attempt to 'free ride' on other small bidders should be less acute in a single-round sealed bid context, as bidders do not have the same opportunity to observe the behaviour of competitors and to adjust their strategies accordingly. Moreover, this effect is only likely to be important to the extent that there are regions where demand in the auction is expected to be very low.

During the NCC's bidder seminars, concern was expressed by a number of bidders that those pursuing single regions would be disadvantaged relative to bidders pursuing aggregations. In general, this may be attributed to self-interest: combinatorial bidding removes the disadvantage that multi-region bidders (with synergies between regions) would face if the regions were being auctioned separately. However, there may be potential for multi-regional bidders to exploit 'gaming' opportunities where there is low competition for one or more of the regions in an auction group. In this situation, multi-region bidders can potentially increase their

[24] Jain (2001).

[25] FCC (2000), 2. Submissions to the FCC on this subject are available at: http://wireless.fcc.gov/auctions/31/releases/.

[26] See in particular: Vohra & Weber (2000), Levin (2000), Milgrom (2000), and Harstad (2000).

chances of having a bid accepted at the expense of rivals pursuing single regions or smaller aggregations by including relatively uncompetitive regions in their combinatorial bids.

Cantillon and Pesendorfer (2002) also identified this "*strategic effect*" in their analysis of the single round combinatorial auction used for allocating London bus licences. They noted the potential for bidders to use combination bids "t*o link otherwise independent markets and leverage any advantage they have in one market into another*."[27] The crucial point is whether the combinatorial bids are reflecting real synergies or simply linking independent demands.

This issue is best illustrated with an example from auction 5, where one region, Ebonyi, had only three eligible bidders – Third Rail, Rainbownet and UBA – for two licences. These three bidders had also bid for at least two of the other regions in the same auction, and so were in a position to include Ebonyi in a combinatorial bid. Had these bidders all chosen not to also make an individual bid on Ebonyi, this could potentially have given them an 'advantage' to the extent that rivals for other regions would not have had any bid in Ebonyi that they could have been paired with. Put differently, these bidders had a potential strategic incentive not to submit a single bid for Ebonyi as it might compete with their combinatorial bids. Whether this would actually be detrimental to efficiency depends on the extent to which these bidders' demands for Ebonyi were really dependent on the other regions. In addition, the lower the value of Ebonyi relative to the other regions in the auction, the less likely that the strategic effect would influence the final outcome.

Overall, the benefits of using a combinatorial auction in terms of eliminating aggregation risks appear to have outweighed any possible drawbacks stemming from the threshold problem. This reflected the apparent strong synergies between regional FWA licences in Nigeria, especially adjacent regions. In practice, bidders did not exploit the gaming opportunity described above (the benefits from attempted to do so were anyway ambiguous in this specific case). Overall, there is no evidence that smaller bidders were disadvantaged: some 24 of the 48 licences sold in the auction were allocated to bidders who had made single-region bids. In all five auctions, there are examples of combinatorial bids which were outbid by 'coalitions' of single region bids made by a number of bidders.

[27] Cantillon and Pesendorfer (2002), p2.

5.4.4 Bidder comprehension and transparency

Given that combinatorial bidding is a relatively new concept in spectrum auction design and that the bid decisions required are more complex than in a standard sealed bid auction, there was concern that bidders might struggle to understand the auction process. However, in general, bidders appear to have coped well with the introduction of combinatorial bidding. Most bidders made intelligent use of combinatorial bids, often making large numbers of bids to reflect preferences between different combinations. In this regard, it is likely that bidders benefited significantly from the bidder seminars prior to the auction and from the use of tailored bid forms.

One concept that some bidders found difficult to grasp was the fact that the highest bid for a particular region or combination will not necessarily be included in the winning set of bids. This occurred a number of times in the auctions, for example:

- **Auction 1.** Third Rail was successful with a bid of 350 million naira for Delta, Rivers & Abuja but had a larger bid of 500 million for Delta, Lagos, Rivers & Abuja rejected. This was because another bidder had bid over 200 million alone for Lagos. Peculiarly, Third Rail had itself made a stand alone bid for Lagos of 220 million, whereas the differential between its successful bid and the 500 million bid implied an incremental value of only 150 million for Lagos. Had Third Rail made a bid of say only 300 million for Delta, Rivers & Abuja, its 500 million bid for all four regions would have been successful.
- **Auction 5.** UBA made a bid of 8,000,010 naira for Gombe, which was one of only two bids received for the two licences in that region. However, this bid was rejected, as it was more efficient to accept UBA's bid of 16,900,000 naira for a licence in Kaduna instead. As a result, one licence in Gombe went unsold. It is not clear why UBA did not make a combinatorial bid for Kaduna and Gombe together, in which case it would have won both licences. UBA did make a combinatorial bid for Gombe, Kaduna, Kano, Nassarawa and Plateau but this was rejected because it was too low.

A broader concern raised about using a combinatorial auction was that while the outcome might be fair, it would not be transparent, owing to the use of a software algorithm to calculate the optimal result. The algorithm was indeed invaluable in quickly and accurately determining the auction results. Nevertheless, given that there were only four or five regions in each auction and most bidders were not eligible to make the full range of combinatorial bids in any one auction, it was possible for third parties to replicate the results manually.

5.4.5 Payment

One issue with using a sealed bid format combined with a system where bidders pay what they bid is that identical licences can sell for very different prices. For example:

- In auction 2, Oracom bid 450 million naira for a combination of Edo, Ogun, Ondo and Oyo. The other four successful bidders bid a combined 377 million naira for the same set of licences, equivalent to a discount of 16%.
- In auction 3, Third Rail bid 235 million naira for a combination of Abia, Akwa Ibom, Cross River and Imo. Other bidders were successful in winning licences in these regions for a combined 145 million naira, equivalent to a discount of 38%.

These differentials do not necessarily affect the efficiency of the outcome. It is still the case that the licences have been awarded to those bidders that value them most. To the extent that some winning bidders have paid more than they would have done if they had been able to observe the bids of their competitors (as would have been the case in a multi-round process), the 'excess' payment represents a transfer of 'surplus' from the bidders to the government.

Moreover, to the extent that licence payments can be considered as sunk costs, differences in payments should not affect the ability of operators to compete in the provision of FWA services, provided players bid rationally.[28] However, in the event that winning bidders have relied on debt to finance their bids, those that paid larger amounts could potentially be in a weaker position if their cost of finance rises more than their rivals as a result of their licence fee expenditure. Nigeria has a very difficult financial environment at present, characterised by high interest rates and short-term lending, so cost of finance is a pertinent issue.

Despite the possibility of modifying the auction algorithm to calculate market clearing prices for licences (i.e. everyone pays the same), this wasn't done, for reasons of transparency. Importantly, the decision to charge bidders what they bid was accepted by bidders and observers as fair and transparent despite the difference in some of the payments for identical licences. Nevertheless, it is possible that payment inconsistencies were a factor in the decision of some of the winning bidders to default: at least three of the defaulters had bid substantially more than the next highest bidders. The forfeited deposits, which collectively totalled 93 million naira, had been set on

[28] Binmore and Klemperer (2001), C77-78

the basis of much lower revenue expectations than were realised, and were thus probably only a marginal deterrent to default. It is unclear whether these bidders had simply bid above their financial capacity or thought they could save money by defaulting and seeking deals with other licence winners.

More generally, payment default appears to be a common problem in developing countries. In Nigeria, one of the country's GSM licences was unsold after a winning bidder defaulted, and the efforts to privatise NITEL was marred by bidder payment problems. Similarly, India's auctions of GSM and basic services licences suffered several defaults, "as the winners claimed they had bid too high".[29] The use of deposits, anti-collusion rules and additional penalties[30] in the Nigerian FWA process served to reduce exposure to default. However, it is doubtful that any realistic rules could have eliminated this risk altogether. Fortunately, the final level of default was not sufficient to undermine the success of the overall process. An interesting story for the future will be whether the other licence winners can succeed in building viable FWA businesses across Nigeria.

6 Conclusion

In 'developed' countries, the growth in the use of auctions to allocate spectrum has primarily been driven by a desire to promote allocative efficiency. This objective is shared by forward-thinking regulators elsewhere; however, in countries where there is a history of problems with corruption, the transparency benefits of an auction are often just as important as efficiency. The success of the Nigerian FWA process, like the GSM auction before it, can in large part be attributed to the fact that both bidders and the public perceived the process to be fair and transparent. It is unlikely that this would have been the case with either a beauty contest or an auction process with less than complete information revelation.

The choice of auction design should be influenced by many factors, including the objectives of the allocating body, the level and structure of demand for lots, and logistical constraints. Where the characteristics of demand are uncertain, it is helpful to design a process that reveals information about characteristics of bidder

[29] Jain (2001).

[30] For example, bidders subject to forfeiture were barred from participating in future NCC licensing processes for a minimum period of five years.

demands before a final decision on an auction design is made. In this way, the allocating body can avoid committing itself upfront to an auction format that may turn out to be inappropriate. This is particularly important where there are awkward logistical constraints, such as deficient communications infrastructure.

The use of an initial application stage to reveal specific information about the level of demand by region and the linkages in demand between regions was instrumental in the decision to adopt a sealed bid combinatorial auction design. In designing a multi-stage process, it is essential that bidders have reasonable incentives to reveal the true nature of their demands in the initial stages; otherwise, the decisions about the auction design may be made on erroneous information. In Nigeria, this was done by inviting binding applications at a fixed reserve price.

This was the first time that a combinatorial process has been used to allocate spectrum licences. The success of the auction in Nigeria suggests that simple combinatorial approaches do not pose significant problems for bidders, provided that they are properly instructed.

Klemperer has suggested that sealed bids may be more appropriate than multi-round auctions where competition is weak or collusion is a concern. Combinatorial bidding provides a tool for extending sealed bids to situations where separate sealed bids for each lot could produce grossly inefficient outcomes. In addition, in situations where there are strong synergies between lots and it is impractical or not cost-effective to run a multi-round auction, combinatorial bidding can make a sealed bid process more efficient. This is particularly likely to be the case in developing countries, where it is often not possible to rely on local communications infrastructure to run auctions remotely, and co-locating large numbers of bidders for long periods of time may be prohibitively expensive.

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