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Fixed or flexible: the 2.6GHz spectrum awards

Is spectrum so valuable?

The current era is undoubtedly one of transformation in the mobile industry. Newly available spectrum bands are being awarded on a liberalized basis and the liberalization of spectrum bands traditionally restricted to usage for providing specific services is progressing full throttle. With this comes the potential for the emergence for new services and the provision of old services at lower cost, and all that this implies for the change in landscape amongst mobile service providers and the possibilities of dislocating competition.

As consumers begin to take advantage of the services that become available over the coming years, the availability of mobile spectrum that is harmonized across countries will need to grow significantly to meet the needs of telecoms operators and the customers that they serve. Given that the total amount of spectrum available for award is finite and spectrum licences are relatively long, the importance of allocating spectrum efficiently across the many potential users is great.

The 2.6GHz band is part of a family of spectrum bands identified for the deployment of mobile services worldwide. Since 2007, nine European regulators and one Asian regulator have announced detailed plans to award 2.6GHz spectrum by auction to allocate this spectrum efficiently; seven of these auctions are now complete. This article surveys the spectrum packaging, auction format and auction rules chosen by National Regulatory Authorities (NRAs) as part of their respective 2.6GHz spectrum award processes and the impact of these choices on auction outcomes.

In principle, the 2.6GHz band provides an opportunity to test the concept of spectrum liberalization, with two competing technologies: LTE (using paired spectrum) and WiMAX (using unpaired spectrum). However, the decline in market sentiment towards WiMAX has weakened the case for flexible band plans that allow the market to determine how frequencies are allocated across these technologies.

There have been significant differences in the prices achieved for paired spectrum in the seven auctions completed so far. We argue that the primary cause of price variation is modest but significant differences in the level and structure of demand across countries exist. Moreover, in many cases, there is evidence that regulatory decisions on spectrum packaging have had an impact on demand and bidder behavior. For example, there is evidence that the combinatorial clock auction format may be less vulnerable to demand reduction than conventional SMRA auction formats.

The background

The 2.6GHz frequency band is part of a family of bands identified worldwide for deployment of mobile services. Also known as the 2.5GHz band or 3G expansion band, it includes 190MHz of spectrum from 2500 – 2690MHz. Almost uniquely, these same frequencies (with modest local variations) are potentially available for mobile services in all regions of the world. The band could be used to deliver a variety of services, including wireless broadband, via phones or data cards, and mobile TV, using a variety of technologies. In particular, there are two main candidate uses:

- LTE, a cellular mobile technology that uses paired (FDD) spectrum; and
- WiMAX, a broadband technology that uses unpaired (TDD) spectrum

Both of these technologies can and are being deployed in other spectrum bands worldwide. Amongst bands identified for mobile services, the 2.6GHz band is located at relatively high frequencies, meaning signals travel shorter distances. For this reason, it would most likely be used to provide capacity for high-speed broadband connectivity in urban areas. LTE systems are designed to be deployed within the 2.6GHz band using paired spectrum with 120MHz duplex spacing. By contrast, WiMAX is designed to work anywhere in the band but requires at least 5MHz spacing from any other use (including LTE and other WiMAX users) so as to avoid undesirable interference.

The ITU has proposed three possible options for packaging of the spectrum as depicted in Figure 1:

» Option 1: Two paired blocks of 70MHz each for FDD, with a 50MHz centre band for FDD

» Option 2: Two paired blocks of 70MHz each for FDD, with a 50MHz centre band for FDD downlink linked to an external band

» Option 3: Flexible allocation between FDD and TDD

To date, regulators have focused primarily on Options 1 and 3. Option 2 can largely be disregarded as there is scant evidence of demand from operators to use the centre band for FDD downlink. This is unlikely to change in the foreseeable future, as equipment manufacturers are prioritizing deployment of LTE using the paired spectrum within the 2.6GHz band. It should be noted that Option 1 is a specific outcome possible under Option 3. Therefore, depending on the award mechanism, adoption of Option 3 does not preclude an Option 1 outcome.

Within Europe, the CEPT has proposed a band consistent with the ITU Option 1, that is, 2x70MHz of paired spectrum (2500-2570MHz paired with 2620-2690MHz); and a 50MHz unpaired centre band (2570-2620MHz). This supports the maximum deployment of LTE with a fixed 120MHz duplex split. European countries are not obliged to follow the CEPT plan. Indeed, under European Union policy, they are supposed to take technology and service neutral approach towards competing TDD and FDD systems.

Some of the first European countries to develop auctions of 2.6GHz frequencies opted for a liberalised approach to spectrum assignment that encouraged aspiring LTE and WiMAX users to compete directly for the same spectrum (variations of ITU Option 3).

These auction designs were formulated at a time when the relative demand for paired and unpaired was uncertain. However, more recent designs have tended to favor fixed band plans, which are only nominally technology-neutral, consistent with ITU Option 1 and the CEPT plan. The shift towards a more conservative allocation approach appears to be driven by a perception that LTE use is likely to generate higher value than WiMAX, and by concerns about interference co-ordination at national boundaries. Recent auction results appear to support this view.

Differences in prices appear primarily linked to local levels of competition within the auctions. There is insufficient information to make a judgement whether particular design choices have made a positive or negative impact on the efficiency of final assignments. However, there is evidence that design choices in relation to packaging, auction rules and reserve prices may have affected participation decisions and bidding behavior, and thus price outcomes.

The final part of this article summarizes our findings. We observe that the trend away from a truly technology neutral approach appears to be driven primarily by pragmatic reasons. At the margins, the preference for fixed band plans may weaken competition, but this no longer appears to be a critical issue, owing to the decline in market sentiment towards technologies using unpaired spectrum relative to LTE use of paired spectrum. Of greater interest is the role of regulatory decisions on packaging and auction design in affecting participation and bidder behavior, and the impact this can have on price outcomes in situations where there is only modest competition.

Key choices in packaging

When designing lots for an auction of 2.6GHz spectrum, regulators face four main decisions:

Whether to make an administrative decision on the allocation of spectrum to FDD and TDD, or devolve this to the market. Historically, regulators have made administrative decisions on allocations that narrowly define the types of services and technologies that can be used in each frequency band. However, this approach raises concerns that regulators may pick the 'wrong' technologies or that market conditions may change too quickly for regulators to respond by re-planning. In response, many regulators have (at least nominally) embraced a technology- and service-neutral approach to spectrum management.

» If relevant, how much spectrum to allocate to FDD and to TDD respectively.
» The size of lots available in the auction. One common feature of demand for spectrum for LTE and WiMAX is that both can be expressed as units of 5MHz. In practice, we know that most (perhaps all) bidders are likely to want larger blocks of spectrum.
» How to adapt packaging to minimize uncertainty for bidders over the future interference environment.

To answer these questions, the regulator ideally requires a reasonable understanding of candidate technologies, and the potential level of demand and value creation associated with their deployment. At a minimum, the regulator requires information about the amount of spectrum required to deploy a service, and the compatibility of candidate technologies, both with each other and with uses in adjacent bands.

For the 2.6GHz band, there is a long list of possible candidate uses, including various mobile technologies (UMTS, HSPA, LTE, etc), WiMAX, mobile TV (MBMS) and wireless video cameras. However, amongst these, only LTE and WiMAX stand out as prime candidates for this band, on the basis of value creation potential.

These two uses have very different spectrum requirements:

» Within the 2.6GHz band, LTE ideally requires 2X5MHz carriers with 120MHz duplex spacing, as defined in ITU Option 1. Multiple contiguous blocks – between two and four – are preferred, as this will allow for high speed mobile broadband. LTE users can occupy frequencies immediately adjacent to each other without onerous co-ordination requirements, but they require at least 5MHz separation from medium or high power WiMAX use so as to avoid serious interference.
» WiMAX is deployed using contiguous unpaired spectrum. In principle, it could be deployed with as little as 5MHz of spectrum but in practice larger contiguous blocks (up to 50MHz) are preferred, as this can support higher speed mobile broadband. To prevent serious interference to adjacent users, including other WiMAX users, at least 5MHz separation is required from other users.

Thus even if licences are defined on a technology neutral basis, the packaging structure and usage restrictions may in practice create formidable obstacles to particular technologies using certain frequencies.

Auction format

To date all countries that have sold 2.6GHz spectrum have chosen to adopt open, multiple round auction formats. Open processes have presumably been favored because they allow for price discovery, which is helpful for operators trying to

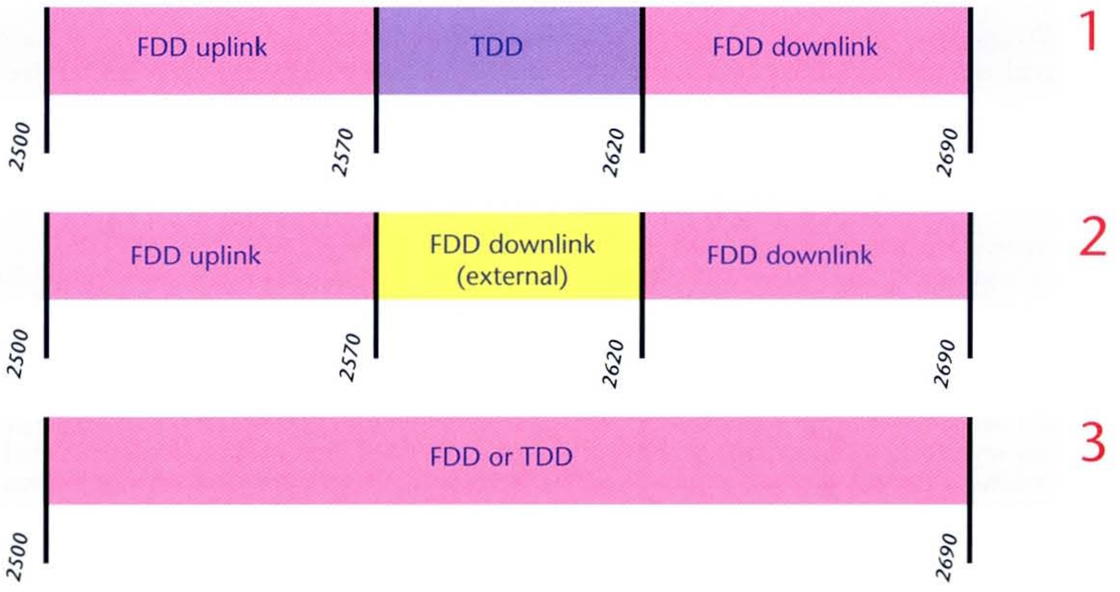

Figure 1

ITU options for the allocation of the 2.6GHz frequency bands

Spectrum auctions

acquire spectrum with potentially high value and facing common value uncertainty.

The ten countries surveyed by us can be allocated to three groups according to their choice of auction format:

Simultaneous multi-round ascending (SMRA) auction: Hong Kong, Germany, and Belgium. This was the most common auction format used in the global wave of 3G auctions in the early 2000s. In the standard implementation, bidders may submit bids for one or more specific frequency lots in each round of the auction and a highest bidder is identified. The auction continues with rising prices for lots in excess demand until no new bids are forthcoming, at which point the remaining bidders win lots where they hold the highest bid.

SMRA with switching: Norway, Sweden and Finland. This approach gives bidders increased freedom to withdraw from bid commitments, provided they make corresponding new bids on equivalent spectrum.

Combinatorial clock auction (CCA): United Kingdom, the Netherlands, Denmark, and Austria. This requires bidders to make just one package bid each round during an open bidding phase, which is then followed by a sealed bid 'supplementary round'. The open phase is intended to allow price discovery, while the final round sealed bid gives bidders the opportunity to express a wide range of preferences across packages.

Auction results

As of June 2010, seven countries had completed their 2.6GHz auctions: Norway, Sweden, Hong Kong, Finland, the Netherlands, Denmark, and Germany. Some other countries, such as Singapore (2005) have previously awarded spectrum in this band but are excluded from this particular consideration as these awards pre-date current technology choices and so are not easily comparable. The revenues achieved in each of these auctions are depicted in Table 1. A breakdown of average prices for paired and unpaired spectrum is provided in Table 2.

A comparison of prices per population per MHz, the standard benchmark for spectrum price comparisons, reveals significant differences between Norway, Finland, Germany and the Netherlands on the one hand, and Hong Kong, Sweden and Denmark on the other:

In Norway, Finland, Germany and the Netherlands, prices for all 2.6GHz lots were low. Despite the general market perception that FDD spectrum is more valuable than TDD spectrum, prices for unpaired lots in Norway and Finland were modestly higher than for paired lots. However, in the Netherlands, the TDD spectrum went unsold. In Hong Kong, Sweden and Denmark, paired spectrum sold for higher prices. Unpaired spectrum in Sweden and Denmark went for a similar (low) price to Norway, whilst Hong Kong failed to attract any bids for TDD lots in the 2.6GHz band.

Why were there such large differences in prices and outcomes? We argue that the primary driver of differences in prices was the level and structure of demand which varied significantly across each country. In some cases, packaging and auction design decisions also had an impact on outcomes.

Both Norway and Finland experienced very low competition, which was predictable given the local market structures. These two countries have two and three national incumbent mobile operators respectively. Thus, without entry, there was little scope for competition for FDD spectrum. Further, the local mobile markets are small and highly developed, which means that there are substantial asymmetries between incumbents and potential new entrants, so conditions for new entry – especially in cellular mobile – are not particularly favorable.

By contrast, the competitive conditions in Sweden, Hong Kong and Denmark were more favorable, as these countries each have four or more mobile operators. This meant that, even without entry, there was likely to be competition amongst incumbents for FDD spectrum. Indeed, in Sweden and Denmark, the relatively high prices achieved for FDD lots were entirely the result of competition between four incumbents, each wanting 2X20MHz of FDD spectrum. In each case, the auction only ended when one of the incumbents dropped demand by 2X10MHz.

As Germany had four operators, one might have expected that prices for 2.6GHz paired spectrum would have reached similar levels to Sweden and Denmark. However, in practice, bidders were more willing to compromise, possibly because they were able to obtain substitute spectrum in other bands, such as 1800MHz and 2GHz. Moreover, the battle that really mattered in the German auction was the competition for 800MHz.

REVENUES FROM 2.6GHZ AUCTIONS

	Pop	Auction	Date	Total spectrum sold (MHz)	Total revenues for 2.6GHz band (local currency)	Total revenues for 2.6GHz band (€)
Norway	4.68m	2.6GHz	Nov 2007	190	NOK 231m	€28.8m
Sweden	9.08m	2.6GHz	May 2008	190	SEK 2100m	€219m
Hong Kong	6.86m	BWA	Jan 2009	90	HK$1540m	€143m
Finland	5.25m	2.6GHz	Nov 2009	190	€3.8m	€3.8m
Netherlands	16.78m	2.6GHz	Apr 2009	130	€2.63m	€2.63m
Denmark	5.52m	2.6GHz	May 2009	190	DKK1010m	€136m
Germany	82.28m	2.6GHz	May 2009	190	€344m	€344m

Table 1 (above) Revenues from 2.6GHz auctions (Source: DotEcon Database of Spectrum Awards. Population data from CIA World Factbook. Conversion to Euros using average annual exchange rate from oanda.com for year of award)

Table 2 (below) Prices in 2.6GHz auctions (Source: DotEcon Database of Spectrum Awards)

PRICES IN 2.6GHZ AUCTIONS

	All 2.6GHz band		Paired spectrum		Unpaired spectrum	
	Total spectrum sold (MHz)	Average price per MHz per pop (€cents)	Total paired spectrum sold (MHz)	Average price per MHz per pop (€cents)	Total unpaired spectrum sold (MHz)	Average price per MHz (€cents)
Norway	190	3.24	120	3.01	70	3.63
Sweden	190	12.70	140	15.90	50	3.65
Hong Kong	90	23.10	90	23.10	Unsold	NA
Finland	190	0.381	140	0.317	50	0.559
Netherlands	130	0.120	130	0.121	Unsold	NA
Denmark	190	13.00	140	17.50	50	0.244
Germany	190	2.20	140	2.24	50	2.10

The Netherlands is an odd case. Although there were only three incumbents, the auction attracted two strong entrants. With five bidders, demand for paired spectrum could have been strong. However, because the spectrum caps on the incumbents were set very tightly, there still was not enough demand to increase prices above reserve. If the spectrum caps had been looser, perhaps there would have been more competition resulting in higher prices. However, this is uncertain because it may have been the presence of the spectrum caps that attracted the entrants to join the process.

Notwithstanding these general observations about competition, it also appears that decisions on spectrum packaging, reserve prices and auction design have had an impact on outcomes. A number of observations can be made:

Finland suffered lower prices than Norway, despite having one more national operator. There are two possible explanations for this, in addition to lower participation. First, unlike Norway, Finland adopted a fixed band plan. This meant that competition between two non-incumbents for unpaired spectrum had no impact on prices that the mobile operators paid for paired spectrum.

By contrast, Norway's flexible band plan obliged incumbent operators seeking FDD spectrum to compete directly with aspiring TDD entrants, thus driving up the price of spectrum suitable for either use. Secondly, Finland's peculiar implementation of the SMRA switching rules enables FDD bidders to manipulate prices down as well as up, so even the price impact of limited competition amongst the three incumbent operators was not realized. Hong Kong used relatively high reserve prices, which may have helped to underpin prices for FDD spectrum, where there was demand. However, these prices may have been too high for unpaired spectrum, which went unsold. By contrast, Sweden and Denmark – which used much lower reserve prices – were able to realize demand for TDD spectrum.

The Danish decision to use a CCA rather than SMRA format may have been critical in underpinning prices. In a CCA, which implements a 'second price' rule, the marginal bidder has good incentives to bid up to their value, as they only pay the amount that they would need to have bid to out-bid their competitors, not their actual bid amount.

By contrast, in an SMRA, a marginal bidder may be better off reducing their demand early in the auction in the hope of getting lower prices, as if they keep bidding, they will have to pay higher prices even if they reduce demand. Of course, this can have a huge impact on what other winning bidders pay. In both Sweden and Denmark, the list of bidders was similar and the marginal bidder was the same company: Hi3G. On the basis that Hi3G could reasonably have predicted it was likely to be the marginal bidder, one may surmise that the outcome of an SMRA could have been one with significantly lower prices.

The choice of spectrum caps in the Netherlands was arguably unfortunate. Maximum demand across the three incumbents and two entrants exactly matched supply of FDD spectrum. If the caps had been slightly higher, this might have been enough to generate modest excess demand and thus competition in the auction.

In conclusion, the most important factor determining different price outcomes in 2.6GHz auctions to date is the level of competition. Nevertheless, it is often possible to anticipate low participation, and there are measures that regulators can take to increase the likelihood of competition and safeguard prices. A comparison of Norway versus Finland suggests some benefits from using packaging approaches that facilitate direct competition between TDD and FDD bidders. Meanwhile, in Denmark, the decision to use a CCA format with second prices may have been critical in eliciting demand from all four bidders in a situation where there might otherwise have been strong incentives for demand reduction. Finally, higher reserve prices may help to underpin revenues but if set too high, may lead to lots going unsold.

Summary

In principle, the global awards of the 2.6GHz band provide an opportunity to test the concept of spectrum liberalization. As the original UK[1] and Dutch approaches demonstrate, it is possible to construct an award format that creates a reasonably level playing field for aspiring FDD and TDD operators to compete for the same spectrum,

1 Ofcom had originally planned a flexible band plan CCA auction in 2008 for the award of 2.6GHz spectrum in the UK; however, those plans were revised following litigation from mobile operators and a recommendation from the independent Spectrum Broker to postpone the award of 2.6GHz spectrum until a joint award could be held for this spectrum and spectrum in the 800MHz band.

while precluding undesirable fragmentation of the band between technologies.

This can be achieved through the adoption of a flexible band plan with fungible, generic lots and a package bid auction format. Norway's approach also fostered competition between FDD and TDD bidders, but the use of specific lots in an SMRA type format did not preclude fragmented outcomes.

In practice, most countries have shied away from the relatively radical approach of flexible boundaries, instead favoring the fixed CEPT band plan, which is only nominally technologically neutral. There are pragmatic reasons for taking a conservative approach. Over the last 18 months, sentiment has shifted significantly in favor of LTE technology and against WiMAX, with the implication that TDD users are much less likely to outbid their rivals deploying FDD-based technologies. Further, for any country that has significant population centers in border areas, frequency co-ordination may be more complicated if they adopted approaches that differ from their larger neighbors.

The shift away from flexibility is not without cost. Two concerns stand out. Firstly, as successive countries lock themselves into the CEPT plan, the scope for the launch of TDD systems, such as WiMAX, becomes more constrained. This may or may not be the efficient outcome, but it is regulators, and not the market, making the decision on spectrum allocation between TDD and FDD. Secondly, by separating TDD and FDD spectrum within an auction, the scope for competition across users of these two technologies is eliminated. This appears to have had a detrimental impact on auction revenues in Finland, but is not relevant for more recent auctions, where demand for unpaired spectrum was relatively low.

The most important story to emerge from the auctions completed to date is the modest level of competition afflicting all the auctions. This is perhaps predictable given that mobile markets are relatively mature and there are strong incumbent operators. Only the Netherlands to date has attracted strong entrant competition for paired spectrum, and that was in a situation where the incumbent bidders were significantly constrained by spectrum caps.

In this context, small differences in the level of demand have lead to very large differences in price outcomes. In Hong Kong, Sweden and Denmark, prices for paired spectrum were strong, with modest excess demand amongst incumbent bidders sufficient to support a competitive auction. By contrast, in Norway, and Finland, which have only two and three incumbents respectively, there was insufficient demand to support high prices. In Germany, prices of 2.6GHz spectrum may have been reduced owing to the availability of substitute spectrum in other bands, and possible incentives for demand reduction to reduce prices. In the Netherlands, the caps on incumbents were too tight to support any excess demand, despite there being two entrant bidders.

In summary, differences in price outcomes can largely explain the variation in demand levels in the 2.6GHz auctions. However, the packaging and auction design decisions made by regulators can and do have an impact on demand and bidder behavior. As a general observation, the CCA is less vulnerable to demand reduction than the SMRA, as marginal bidders are not exposed to higher prices if they bid up to their value. The use of a CCA was probably critical in underpinning prices in Denmark by creating effective competition between incumbents. Other decisions, such as the level of spectrum caps, the amount of bid information released during the auction, and the level of reserve prices can also make a big difference to outcomes.

Eimear Sexton has been involved in the Dutch 2.6GHz auction, the Indian 3G and BWA auctions and the Canadian AWS auction at DotEcon. Eimear is at present involved in the design of an auction for 800MHz and 900MHz spectrum in Ireland, an auction of 900MHz and/or 1800MHz spectrum in Malta and the forthcoming auction of spectrum in multiple bands including 800MHz in the United Kingdom. Arisa Siong has a BSc and MSc in Economics from the London School of Economics. At DotEcon, she has worked on a variety of analytical and research-based projects involving setting spectrum charges, the use of market forces in spectrum management, digital dividends in Europe, spectrum trading and auction design and implementation. In addition, Arisa manages DotEcon's Spectrum Awards Database.