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ABSTRACT

This paper presents a methodology for setting fees for the renewal or extension of spectrum licences, by using the outcome of an auction for comparable licences but with a different licence period. The methodology is a combination of market and cash flow valuation and consists of two main steps. First, prices for spectrum corresponding to that of the licences to be extended are derived from the auction outcome. Second, the relative value addition of the extension period for the new licensee, compared to the value of the licences auctioned, is derived by using a model for the development of EBITDA for an operator over time. A combination of these two is used to calculate fees that match the opportunity costs of extension. Thus, optimum alignment is achieved with the policy objective of using licence fees only to promote efficient use of spectrum, while avoiding state aid at the same time.

1. Introduction

In developed countries, spectrum licences for wireless communication are mostly awarded by means of an auction or a beauty contest or hearing (Zaber & Sirbu, 2012). Spectrum licences commonly have a predetermined duration. When they expire, governments can award them again, or under certain circumstances they can opt for renewal or extension. In the latter situation, licensees are offered the option to continue using the spectrum. Such an extension can be for a limited period, for instance to accommodate a transition, for a full new licence term or even indefinitely, and may be used to facilitate a change in the licence conditions concerning the use of spectrum. Setting the appropriate licence fees is an important issue in such cases (Guermazi & Neto, 2005).

This paper describes how licence extension fees can be calculated if market information about the value of spectrum is available from a spectrum auction including the same or similar frequencies but for a different licence period. A methodology is presented which involves deriving prices from an auction that correspond to the extended licences in terms of underlying spectrum, and adjusting these for the deviating licence period by means of the curve describing value creation over time for a mobile network operator. Taking the auction outcome as a starting point implies the use of market information on the value of frequency bands and optimum alignment of the extension fees with the policy objective of using licence fees only to promote efficient assignment and use of spectrum, whereas state aid is avoided at the same time.

This paper is organized as follows. Section 2 provides a brief discussion of the literature and regulatory context of spectrum assignment, licence renewal or extension, and setting licence fees. The theoretical framework proposed for setting

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licence extension fees based on an auction is presented in Section 3. Section 4 elaborates this framework, after which Section 5 applies this methodology to a Dutch case study concerning the extension of licences for 900 and 1800 MHz bands. Section 6 concludes.

2. Literature and regulatory context

There is extensive literature on auction design,[1] and there is some literature in which auctions are compared with beauty contests or alternative procedures to award spectrum. Auctions score high on the efficiency, non-discrimination and transparency of the assignment procedure (Kruse, 2004). On average, they raise larger public revenues than beauty contests do and have no negative and perhaps even a positive effect on the speed of technology diffusion (Zaber & Sirbu, 2012). Moreover, they are generally claimed to promote efficient use and assignment of spectrum, for in a well-designed auction, licences are won by the most efficient operators that can create most value by using them (Bohlin, Madden, & Morey, 2010; Cave et al., 2007; Hazlett & Muñoz, 2009).

Much less research has been done on the economics and pricing of licence renewal or extension, despite the fact that certain circumstances can render renewal or extension of licences preferable – or even necessary to new assignment in an auction. Generally, licence renewal can be beneficial from the perspective of ensuring certainty for incumbents and thus encourage investment (Guermazi & Neto, 2005). However, this may be detrimental to competition and innovation in the market if it entails that new players cannot enter. On the other hand, renewal might be opted for to encourage incumbents to invest in new technologies or standards (Kerste, Poort, & van Eijk, 2012), thus actually promoting or speeding up innovation.

Licence extension for a shorter period can be desirable to match the licence periods of various spectrum bands, which can then be combined in a multiband business case. In such cases, auctioning separate licences for the short time required to match licence periods is no option, since no other operator would be able to build a business case on such a short licence period. A temporary extension can also be required to allow for an orderly transition without any disruptions for subscribers, if there is too little time between the expiration of licences and the start of newly auctioned licences. Since mobile network operators (MNOs) base their investments in grids and base stations on the spectrum allocated to them (Lundborg, Reichl, & Ruhle, 2012), they may need time to make the transition from their old licences to the new ones. This was the background for the Dutch case described in Section 5.

If renewal or extension is opted for, spectrum fees have to be set administratively. The relevant question is how to do this. In Europe, the regulatory context for frequency distribution and the renewal of licences for frequency use have been laid down in the Framework Directive (2002/21/EC) and are further addressed in the Authorization Directive (2002/20/EC). These directives do not include any specific provisions with regard to licence renewal or extension, but there are some general criteria that can be considered applicable to licence renewal or extension, especially when it comes to imposing fees. According to consideration 32 of the preamble of the Authorization Directive, fees may be imposed to ensure optimum use of spectrum but should not hinder the development of innovative services and competition in the market. Hence, revenue maximization can be no objective in itself, and fees should be no higher than what is necessary for efficient assignment and use of spectrum.

On the other hand, setting licence fees too low could involve impermissible state aid under European law, as it could entail a waiver of state resources (in this case spectrum) to the selective benefit of current licensees. General criteria should be used to find out if state aid is provided for a renewal. These criteria can be largely derived from Article 107 of the EC Treaty and case law of the Court of Justice. For instance, allegations that licence fees for the fourth French 3G operator Free Mobile had been set too low, led to state aid investigations, after which the European Commission ruled that the procedure did not involve state aid (Hocepied & Held, 2011).

To be in conformity with the criteria above that follow from the European Regulatory Framework, the methodology presented in this paper takes the opportunity costs of the extension for the incumbent as a benchmark. In Section 3, it is argued that this methodology promotes optimal assignment and use of spectrum. Conceptually, this methodology relates to Administrative Incentive Pricing (AIP), which was developed by NERA/Smith for the UK Radiocommunications Agency (Marks, Viehoff, Saadat, & Webb, 1996). AIP was formally introduced in 1998 and was evaluated and revised by Ofcom in 2009–2010 (Ofcom, 2009, 2010a). It is used to set fees for both commercial and public spectrum "to reflect the opportunity cost of spectrum denied to other uses and users, rather than just the costs of managing the radio spectrum" (Ofcom, 2009, p. 1). This encourages spectrum users to use spectrum more efficiently and release it wherever they can.[2] Along similar lines,

[1] See for instance Klemperer (2004) for an introductory overview, or Chapter 5 in Cave, Doyle and Webb (2007) for a basic assessment of the pros and cons of various spectrum auction formats.

[2] Licences that were awarded in a commercial setting (such as on auction) and could be traded, were initially exempted from AIP. For such spectrum, the market mechanism was believed to provide sufficient incentives for efficiency. Ofcom focused on costs to calculate fees, which resulted in fees that were not in line with commercial values on which market parties would base auction bids. After a government directive in 2010 requiring "Ofcom to revise the fees payable for licences to use radio spectrum in the 900 MHz and 1800 MHz bands so that they reflect full market value" (Ofcom, 2013, p. 3), this was changed, and fees in these two spectrum bands were based on a range of evidence, particularly including results of the UK 4G auction and foreign auction results. Note that this use of auction results is still in line with the opportunity cost approach that underlies AIP and the methodology presented in this paper.

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the Australian regulator proposed an opportunity cost approach for administrative spectrum pricing, claiming that "[p]ricing based on these principles is expected to promote productive, allocative and dynamic efficiencies in spectrum markets and related downstream markets" (ACMA, 2009, p. ii). As a general approach to setting administrative spectrum fees, the opportunity cost approach which underlies AIP has not met with any serious competition so far.

Setting administrative fees for commercially exploitable spectrum based on opportunity costs usually involves either the development of business cases for other users or uses, or a benchmark of spectrum prices from auctions or secondary market transactions in other countries. The benchmarking approach is used by DotEcon (2013). Business cases are developed by Cambini and Garelli (2011) for estimating the opportunity costs associated with the spectrum formerly used for analogue TV (the digital dividend) and by Kerste, Poort, and van Eijk (2012) and Ofcom (2006, 2010b) for determining an extension fee for commercial radio licences. Poort et al. (2006) use a full business case to determine the fee for a three-year extension of 900MHz GSM licences based on opportunity costs.

The approach of developing *business cases* to set extension fees has the advantage that it is generally applicable. Disadvantages are that it is administratively burdensome and likely to be subject to controversy and litigation, because it is sensitive to assumptions about the costs and revenues of network operators and their strategies towards spectrum use and network investments. Basing renewal fees on a *benchmark* is possible if recent market outcomes from other countries are available. In theory, this yields fees that meet the requirements of the regulatory framework by being market-based. In practice, it can be as burdensome and controversial as the former approach, since it requires taking due account of a host of country-specific differences, such as population size and density, geography, GDP level, market structure, rollout obligations, spectrum availability in other bands, whereas relevant data points diverge and are limited in number. Although the outcomes of spectrum auctions in various countries can to a large extent be understood on the basis of the underlying licence characteristics and market conditions (Bohlin et al., 2010), there is still considerable unexplained variation in auction outcomes between countries that will impact valuation. Moreover, differences in licence duration have non-linear effects which should be taken into account when benchmarking licence fees.

This paper presents a combination of business case valuation and benchmarking for setting extension fees, in the case that market-based valuations for similar licences in the same market are available. These are corrected for non-linear effects caused by discounting and the growth of revenues over the licence period, on the basis of a simplified business case and a generally applicable calculation. Given the fact that recent information about market valuation in the same market is available, this approach is administratively less burdensome and less assumption-sensitive. It is founded on the same economic principle of opportunity costs, and by deriving fees from a market outcome, state aid is prevented. This approach is also related to Bazelon and McHenry (2013), who use a combination of market valuation and discounted cash flow for spectrum valuation outside the context of licence extension.

3. Theoretical framework

Economic theory offers, in broad terms, three ways to assess the economic value of an asset: reproduction costs, market value or cash flows. Reproduction costs cannot be used for spectrum, since it is a non-storable, non-reproducible good. Market value can be used for goods that are tradable and sufficiently liquid. For spectrum, a liquid market does not exist,[3] but auction outcomes can be seen as market valuations for licences. However, as argued in the previous section, these valuations are based on specific licence conditions and duration, at a specific moment in time, and given a specific economic and competitive environment.

Discounted cash flow (DCF) valuation can be used for non-tradable and non-reproducible unique assets, like spectrum licences. In this approach, the value of a licence is calculated on the basis of the net present value of the cash flows that an operator can create with the licence over the licence period. In theory, this equals the value attributed to the licence by the operator and thus the maximum price he is willing to pay in an auction. Since an incumbent has already sunk specific investments in operating the licence, for instance by making investments in a network and marketing, and acquired a client base, he will most likely have the highest valuation for the spectrum. However, charging an operator his own maximum value for extension would be at odds with the regulatory framework, which does not allow revenue maximization. This would punish the incumbent for its success and specific investments by extracting the rents associated with these. Moreover, it would not equal the theoretical market price, because in general an efficient incumbent would not have to pay his own maximum value to win the auction but that of his contestant to outbid him. Therefore, for the licence fee to be in concord with the regulatory framework, it must be based on the value of the spectrum for the contestant instead of on the value for the incumbent. This contestant can be either an entrant or another incumbent who operates less or different spectrum and will determine the outcome of a hypothetical, efficient auction. The net present value for the contestant thus represents the opportunity costs of the incumbent who extends or renews his licence, and a fee derived from it avoids revenue maximization beyond what is necessary for optimum assignment of spectrum.

For a relatively short licence extension, DCF valuation of an entrant's business case will probably not yield a positive outcome. Yet, this does not imply that the spectrum is worthless for anyone but the incumbent and that it can be extended

[3] As Trosby, Johannessen, and Rabstad (2010, p. 36) note, requirements for rollout and coverage "do not go well together with a fluent and well-functioning second hand market."

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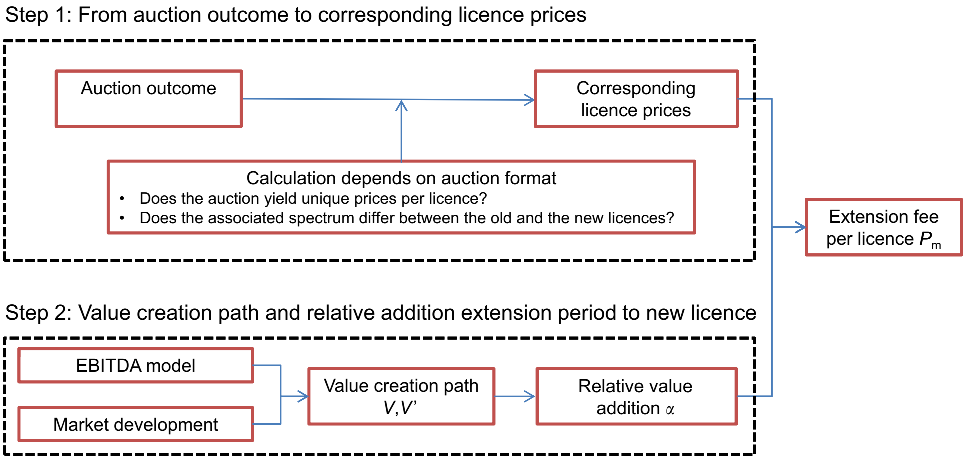

Fig. 1. Analytical framework.

without a fee. As a result of the extension, a contestant in a subsequent auction can acquire the underlying spectrum later and for a shorter period. Acquiring it earlier and for a longer period, which would be the case without the extension, would add value for the contestant, and this extra value equals the maximum price he would be willing to pay for the hypothetical licence extension, which equals the opportunity cost for the incumbent and hence the appropriate extension fee.

In the absence of any market based valuation, these opportunity costs could be assessed by modelling two business cases for the contestant: a *base case* according to the subsequent auction and a *hypothetical case* that includes the preceding extension period (see Poort et al., 2006). As was stressed in Section 2, this approach is administratively burdensome, however, and susceptible to litigation over the many assumptions required for these calculations. When a recent auction outcome for similar spectrum in the same market is available, however, this outcome can be used to derive these business cases in a calculation which is market-based and requires much less information and fewer assumptions. A detailed description of this approach is given in the next section.

4. Analysis and results

The methodology presented in this paper consists of two main steps. First, prices corresponding with the licences to be extended are derived from the auction outcome. Second, because the licence periods of the extension and the auctioned licences differ, the relative value addition of the extension period for the new licensee is derived by using a model for the development of EBITDA for an operator over time. Fig. 1 gives a schematic overview of these two steps and the underlying elements. These steps are described in more detail in Sections 4.1 and 4.2. A combination of these two is used to calculate extension fees.

4.1. *Step 1: From auction outcome to corresponding licence prices*

The complexity of the calculations in this first step depends on the auction format used, and the extent to which the spectrum associated with the extended licences corresponds to that of the newly auctioned licences. If spectrum associated with each new licence is identical to that of a preceding (extended) licence, and if the auction yields a unique price for each licence, this first step is trivial. Most auction formats, such as sealed bid auctions, simultaneous ascending auctions, and ascending clock auctions, do yield a unique price for each new licence.[4] Combinatorial auctions only yield prices for packages of licences, which makes it somewhat more complex to derive a price for each licence for calculation purposes (see the Dutch case study in Section 5).

In ascending auctions, prices are generally identical for licences within the same frequency band, or they may exhibit differences that result from a sequential auction in case there are quality differences within frequency bands. In sealed bid auctions, the auction price for (nearly) identical licences may differ substantially, in which case it is most straightforward to use the average prices of such licences for setting extension fees.

For any of these auction formats, the associated spectrum may differ between the old and the new licences. This requires calculating hypothetical auction prices for the licences to be extended. The most straightforward and objective approach for

[4] For a general discussion of these auction formats, see for instance Chapter 5 in Cave et al. (2007) or Klemperer (2004).

this is to assign the auction prices uniformly to the underlying spectrum and to aggregate this over the spectrum underlying the old licences.[5]

It follows that there is no one-size-fits-all calculation in this first step. The business case in Section 5 provides a calculation for one of the most complex examples: differing spectrum and a combinatorial clock auction lacking unique prices per licence. Other combinations of auction format and spectrum characteristics can be calculated based on the same methodology, leaving out calculation steps where necessary.

4.2. Step 2: Value creation path and relative addition extension period to new licence

4.2.1. Relative value addition α

Consider two alternative licences: one that starts after the extension and lasts T years, and one that is equal to the first but starts E years earlier as it *also* covers the extension period.[6]

The net present value (NPV) which the contestant derives from the first licence is called V and is described by[7]

$$V = \sum_{i=1}^{T} \frac{CF(i)}{(1+D)^{i-(1/2)}}(1+D)^{-E} \tag{1}$$

Here, $CF(i)$ represents the real net cash flows a contestant expects in year i. V is calculated per the *first day of the extension period* with the use of a real discount factor (D) and on the assumption that cash flows are realized halfway each year on average.

The NPV of the second licence that includes the extension period is called $V'$and, calculated for the same date, is described by

$$V' = \sum_{i=1}^{T+E} \frac{CF(i)}{(1+D)^{i-(1/2)}} \tag{2}$$

As set out in Section 3, the appropriate extension fee F for the existing licences equals the value an earlier start and longer duration of the new licence would add to the contestant's business case. Under the likely assumption that $V' > V > 0$, this is

$$F \equiv V' - V \equiv \alpha V \quad \text{in which} \quad \alpha \equiv \frac{V' - V}{V} \geq 0 \tag{3}$$

To determine the extension fee, it is therefore required to estimate α, the relative value addition resulting from an earlier start and a longer licence period, and to multiply this by the auction-based corresponding licence price derived in the former section.[8] The value of α can be calculated from $CF(i)$ and D, given the licence term T and extension term E.

4.2.2. Modelling cash flows by EBITDA over time

In Eqs. (1)–(3), the growth path of value creation by the development of net cash flows is described. However, because only the *relative* development of value creation during the business case is relevant for α, sensitivity for underlying assumptions in a model-based valuation is tempered considerably. This allows for using Earnings Before Interest expenses (or income), Taxes, Depreciation and Amortization (EBITDA) as a proxy for net cash flows. While there is insufficient data available on free cash flows, this allows for a simpler, less assumption-sensitive regression analysis based on readily available data on EBITDA. Using EBITDA as a proxy for net cash flows is not uncommon. There is, however, one element that could distort results. Companies with high depreciation values often also have high investment and reinvestment needs. This will not impact EBITDA, but it will impact net cash flows. Because only relative developments of value creation are relevant here, which implies that the investment effect will be on both sides of the equation, investments do not impact results substantially, and EBITDA can be used as a proxy for net cash flows.

Thus, α is calculated by means of a model which predicts the EBITDA for telecom operators over time. To do so, a panel set with historic public data of comparable European mobile telecom operators has been analysed. This resulted in an econometric model for EBITDA, based on pooled generalized least squares (GLS) estimation with random effects.

The use of panel data to estimate EBITDA directly might result in incorrectly attributing total market development as well as inflation to the number of years active. This would entail overestimating company EBITDA development in time. Therefore, EBITDA values have been divided by the total mobile telecommunication turnover for the relevant country and year. This also facilitated the comparison of EBITDA development between companies operating in markets of different sizes.

[5] If licences remain unassigned in the new auction, the reserve price in the auction could be used in this calculation as the best estimate of the value of these licences, although one can argue that in such a case the auction outcome indicated that the reserve price was set too high and a lower price should be used.

[6] For the sake of brevity, T and E are assumed to be integer values. If they are not, the last term $CF(i)$ in the summations (1) and (2) has to be corrected to account for this last partial year.

[7] In line with basic corporate finance, the value of an investment is calculated by discounting all cash flows using a discount factor, for which most commonly the WACC (weighted average cost of capital) is used. For a further discussion on net present value and the WACC, see for instance the standard text book on principles of corporate finance by Brealey and Myers (2003).

[8] Note that it is assumed here that the winning prices in the auction are due before the extension period, in line with Eq. (1). Different requirements for the payment of licence fees and extension fees would alter the discounting in these equations somewhat but would not change the analytical approach.

Table 1
Dependent and potential explanatory variables.

Variable name	Variable definition	Data source
EBITDA/SIZE	Earnings before interest expenses (or income), taxes, depreciation and amortization of MNO, divided by total turnover from mobile telecommunications in the MNO country.	EBITDA values from Amadeus database (Bureau van Dijk) and annual reports. Total mobile turnover from Telecommunications database, OECD.[a]
AGE	Number of years MNO has been active in its country at the end of the calendar year.	www.mobileworldlive.com, The Netsize (2005–2011).[b]
PSTART	Market penetration rate of mobile telephones in the MNO country in the year of its market entry. This number depends on the year of entrance but does not change over time for MNO.	Telecommunications database, OECD. Based on the number of mobile connections and the number of residents per country.
PRATE	Market penetration rate of mobile telephones in a given country and year.	Telecommunications database, OECD.[a] Based on the number of mobile connections and the number of residents per country.
NUM	Number of MNOs active in a given country and year.	The Netsize Guide (2005–2011).
LOSS3GMNO	Loss of market potential for MNO offering only 3G subscriptions.[c] LOSS3GMNO = 100% -/- market share of 3G in a given country (for MNOs offering only 3G); 0% (for other MNOs).	The Netsize Guide (2005–2011).

[a] The most recent year in the database is 2009. Data for 2010 and 2011 is calculated by multiplying 2009 data from the OECD database with growth rates for 2010 and 2011 from the The Netsize (2005–2011).

[b] The beginning of the oldest licence for GSM or UMTS is taken as the starting date. After a merger, the new MNO is included as a new company with the age of the oldest of the merged companies.

[c] Offering only 3G might impact EBITDA potential, if a substantial part of the population does not use 3G yet.

Table 2
Descriptive statistics for variables used to model EBITDA ($N = 202$; 42 MNOs).

	EBITDA/SIZE	AGE	PSTART	PRATE	NUM	LOSS3GMNO
Mean	0.130	12.6	0.197	1.209	3.8	0.015
Maximum	0.373	19.6	1.226	1.853	7.0	0.575
Minimum	−0.036	2.3	0.003	0.764	2.0	0.000
Standard deviation	0.077	3.6	0.280	0.201	0.9	0.082

In view of the innovative and changing character of the telecom industry, data over a relatively recent period has been used (2005–2011). The data set was geographically restricted to MNOs active in the EU-15. Only EBITDAs specific for mobile activities in a specific country have been used (so no values for combinations of fixed and mobile activities or for several countries).[9] This resulted in a data set of 42 MNOs and 202 observations. Since the database consisted of companies with a sufficiently large range for the number of years they had been in business (see Table 2), it could be used to model a growth curve covering the full licence periods in the hypothetical business cases.

Based on market analysis, a number of variables were selected which may be used to predict EBITDA. By including an explanatory variable for the time MNOs are active in a given market, the growth path of EBITDA could be predicted. Table 1 describes the dependent variable, EBITDA divided by market size, and the variables which were tested as explanatory variables, as well as the data sources used. Table 2 presents descriptive statistics for these variables.

These independent variables were used to test several model specifications and functional forms. Table 3 presents the model for EBITDA/SIZE with the highest predictive power. All variables presented in Table 3 have $p < 0.05$. Robustness was checked by analysing results when restricting the data set to saturated markets: leaving out observations with a PRATE lower than 80% or 90% results in only minor changes to the original model. The negative coefficient of 1/AGE reveals that EBITDA relative to market size increases with the number of years an MNO has been active. This corresponds with the intuitive notion that a more mature MNO – with a brand built up over the years, more experience with market specifics etc – will realize higher EBITDA for a given market size. The negative coefficient of Ln(PSTART) indicates that entry in a more saturated mobile market has a negative effect on EBITDA. The same is true for the number of players in the market: more competitors results in lower EBITDA for a given market size.

The model in Table 3 can be used to predict EBITDA during the licence period of the hypothetical business cases, in order to calculate α from Eqs. (1)–(3). To do so, values referring to the specific market in which licences are extended or renewed are required for the explanatory variables in the model, market size and the discount factor D. This is illustrated in Section 5.

[9] This restriction was tested to have no systematic effect on the composition of the data set.

Table 3
Model for EBITDA/SIZE.

Variable	Coefficient	Standard error	*t* value	*p* value
C	0.094	0.022	4.22	0.000
1/AGE	−0.101	0.051	−1.99	0.048
Ln(PSTART)	−0.029	0.007	−4.10	0.000
NUM	−0.0078	0.0024	−3.20	0.002
R^2 (unweighted)	0.26			
Observations	202			

Table 4
Outcome of the 2012 multiband auction in the Netherlands.
Source: Agentschap Telecom (2012).

Band	Period (years)	KPN	Tele2	T-Mobile	Vodafone
800 MHz	17	2 × 10 MHz	2 × 10 MHz	–	2 × 10 MHz
900 MHz	17	2 × 10 MHz	–	2 × 15 MHz	2 × 10 MHz
1800 MHz	17	2 × 20 MHz	–	2 × 30 MHz	2 × 20 MHz
1900 MHz	4	–	–	1 × 14.6 MHz	–
2100 MHz	4	2 × 5 MHz	–	–	2 × 5 MHz
2600 MHz	17	1 × 30 MHz	–	1 × 25 MHz	–
Basic price		€1,349,851,000	€160,813,000	€910,582,000	€1,380,793,000
Extra price		€2,001,000	€0	€99,000	€7000
Total price		€1,351,852,000	€160,813,000	€910,681,000	€1,380,800,000

5. Case study: Setting extension fees for 900 and 1800 MHz licences in the Netherlands

5.1. Auction design and outcome

The methodology in this paper was developed and used to determine extension fees for licences in the 900 and 1800 MHz bands in the Netherlands.[10] Radio spectrum in the 800, 900, 1800 and 2600 MHz frequency bands was auctioned for 17 years in a procedure that started in October 2012. However, existing licences for the 900 and 1800 MHz bands would end in February 2013, leaving only about two months between the expected end of the auction and the start of these new licences. To allow for an orderly transition, the Minister of Economic Affairs offered the licensees an optional extension of the existing 900 and 1800 MHz licences for a period of up to 24 months after the end of the auction (Staatscourant, 2012b). Incumbents would have to pay a one-off licence fee, if they opted for this extension.

The new licences were auctioned by means of a combinatorial clock auction.[11] As was mentioned in Section 4.1, this auction format adds some complexities to the calculation of auction prices corresponding to the extended licences, as it only yields prices for packages of licences. The combinatorial clock auction started with a *simultaneous clock auction* for generic lots per spectrum band, which in its final round yielded prices per band which were to some extent binding but not yet conclusive. Next, there was a *supplementary round* in which participants could decide individually which packages of spectrum they wished to combine and bid a series of prices for different combinations of generic spectrum per band. This round yielded winning prices for packages of generic licences per bidder, which could be higher or lower than the sum of the final clock round prices of the underlying generic lots. The auction was concluded with an *assignment round*, in which the winners of the supplementary round could bid extra prices for specific lots within the bands in which they had acquired licences.

The multiband auction ended on 14 December 2012, and all available licences in the 900 and 1800 MHz bands relevant for extension, were assigned. Table 4 presents the main outcomes of the auction. A total of €3.804 billion was paid for the new licences.

5.2. Calculating extension fees and follow-up

In order to determine the extension fees, the basic prices from the *supplementary round* first had to be translated into prices per licence. This was done by using the prices per licence in band T in the *final simultaneous clock round* (PC_T), which

[10] It was consulted with the licensees during the research process and adopted by the Dutch government (Minister van Economische Zaken, Landbouw en Innovatie, 2012).

[11] Details are described in Staatscourant (2012a). Cramton (2013) gives a discussion of this type of auction which is becoming increasingly popular.

Table 5
The α values for different extension periods in a market with four players.

Extension period (months)	α when auction outcome is determined by	
	Entrant	Incumbent
1	0.0103	0.0088
6	0.0652	0.0569
12	0.1337	0.1167
18	0.2037	0.1778
24	0.2773	0.2420

gives information about the relative valuation of the different frequency bands in the auction:

$$BP_{TA} = \frac{PC_T}{\sum_{assigned\ licences} PC_T} \times \sum_{winners} PS_i \tag{4}$$

Here, BP_{TA} is the basic licence price per band of type T (of all assigned licences A), and PS_i is the total price that winner i pays in the supplementary round.

The extra prices in the assignment round express bidders' preferences for specific parts of frequency bands. These extra prices were uniformly assigned to the underlying spectrum. This was done per 100 kHz because there were some changes in the spectrum assigned to the old and new licences. For instance, if a participant acquired four blocks of 5 MHz in the 1710–1730 MHz frequency range, paired with four blocks in the 1805–1825 MHz range paying an additional €5 million for this, an extra price of €12.5 thousand per 100 kHz was attributed to this part of the spectrum. Corresponding licence prices for the old extended licences were then calculated by aggregating basic and extra prices per 100 kHz over the relevant spectrum.

The next step was to calculate the relative value addition α (see Fig. 1). To this end, values for the explanatory variables as well as market size and the discount factor (D), relevant for the Dutch market, were needed:

- Telecompaper (2012) was used for market size. It provides growth estimations up to 2016. These are in line with historic development and the stabilizing and eventually diminishing growth one would expect for a new technology. For the years after 2016, market growth was assumed to equal an inflation rate of 2%, i.e. 0% real growth.[12]
- The relevant value for the AGE variable from Table 3 depends on the nature of the *contestant* in the auction. This is determined by the nature of the bidders in the two final simultaneous clock rounds. If this is an entrant, AGE = 1 at the end of the first licence year should be taken; in case of an incumbent, the actual age should be taken. In the 900 and 1800 MHz bands relevant for extension, the auction outcome was determined by incumbents. Therefore, the average of the actual age of the three Dutch MNOs was taken in each year during the licence periods.[13]
- The Dutch market is highly saturated. With the diminishing growth of market turnover, a constant penetration rate was assumed from 2012 onwards that is equal to the penetration rate of 125.6% in 2011. For the incumbents, the average penetration rate in the year of market entry was 9.42%.
- For NUM, the number of players that actually purchased spectrum in the auction (4) was taken.
- For discounting real EBITDA per year in Eqs. (1) and (2), a real discount factor of 8.45% was used.[14]

The resulting value of α for various extension periods is presented in Table 5. For instance, the value 0.2420 in the last row means that when the auction outcome is determined by an incumbent, the appropriate fee for a 24-month extension is 24.20% of the auction outcome for a corresponding (17-year) licence. All values refer to a market with four players. The α values for any other extension period and number of players can be calculated by means of the same models. As can be seen in Table 5, extension fees are lower when the auction outcome is determined by an incumbent: as the relative EBITDA growth rate for an incumbent is smaller, the relative value addition of a longer licence period would also be smaller.

After the auction outcomes in Table 4 have been converted into corresponding prices for the extended licences, extension fees can be calculated from the values for α in Table 5. For instance, extension fees per licensee in the 900 and 1800 MHz band for an extension of 24 months are presented in Table 6. The total amount is €447.5 million.

Fees for an optional 1-month to 24-month extension of licences in the 900 and 1800 MHz bands were determined by means of this methodology. The auction, however, brought no major changes in the spectrum allocation in these bands. As a consequence, the Dutch licensees decided not to apply for extension and to arrange the transition by means of mutual agreements instead.

[12] Real-growth rates have been calculated, by using CPB (2012) for 2012–2013 and assuming 2% inflation for later years.

[13] At the beginning of the extension period, KPN, Vodafone and T-Mobile had an average age of 16.90 years, a year later 17.90 etc.

[14] Because EBITDA is a pre-tax cash flow, a discount factor equal to the pre-tax WACC (weighted average cost of capital) is used. The value for the WACC is taken from the Dutch telecom regulator Opta (2010). The Dutch court (CBb) used this report, including the WACC, to set tariffs for mobile communication. As a pre-tax WACC is used, the debt-related tax shield is not taken into account. Because this is a recurring advantage, this will not have any substantial impact on the relative value that is relevant for α.

Table 6
Extension fees per licensee per band for a 24-month extension.

Band	Licensee	Extension fee
900 MHz band	T-Mobile	€95,786,151
	KPN	€118,962,389
	Vodafone	€109,476,200
1800 MHz band	T-Mobile	€66,600,779
	KPN	€45,000,580
	Vodafone	€11,701,189

Given the outcome of the auction, which reduced the need for a transition period, this scenario was attractive for them for several reasons.

First, the auction price for the newly acquired spectrum was due shortly after the auction, irrespective of the extension period. Hence, the longer the extension lasted, the lower the present value of the new licences would be while the auction price due was fixed. After the auction, transition without extension turned out to be technically feasible, facilitating an earlier start of the new licences without additional costs. The fact that extension was not opted for, implied a shorter licence duration at the *end* of the new licences. The cash flows at the end of the licence period, however, are discounted over 17 years and therefore do not weigh up against the costs of licence extension *before* the new licences. All in all, the limited transition needs, combined with the payment scheme and the possibility to start the licence period directly, gave a strong incentive to skip the extension. Finally, the auction yielded considerable revenues, as a result of which the incumbents' cash position deteriorated. This spoiled their appetite to spend any more money on extension.

6. Conclusion

This paper presents a methodology to derive fees for renewal or extension of spectrum licences from the outcome of an auction in the same market, for comparable licences but with a different licence duration. The methodology consists of two main analytical steps. First, prices for licences corresponding with the licences to be extended are derived from the auction outcome. Second, the relative value addition of the extension period for the new licensee, compared to the value of the licences auctioned, is derived on the basis of an econometric model for the development of EBITDA over time. A combination of these two is used to calculate extension fees.

Conceptually, this methodology is a combination of market and cash flow valuation. Taking the auction outcome as a starting point for setting extension fees implies optimum use of market information on the value of frequency bands. This implies that the derived extension fees can be deemed market-based, and applying them entails no state aid. The extension fees are derived from the opportunity costs for the incumbent. Thus, they promote efficient use and assignment of spectrum, as they encourage incumbents not to apply for extension if others can use the spectrum more efficiently.

The methodology is applied in a Dutch case to determine fees for an optional 1-month to 24-month extension of licences in the 900 and 1800 MHz bands. This optional extension was expected to be required for an orderly transition between the expiration of old licences and the start of new licences. The Dutch case study shows the practical use and applicability of the methodology, even against the background of a fairly complex auction format and differences in the spectrum underlying the old and new licences.

The methodology is readily available for any regulator or policymaker who needs to set licence extension fees if extension or renewal is required, for instance to ensure a fluent transition after a spectrum auction or to match licence periods, provided that a recent auction outcome for comparable licences in the same market is available.

This methodology has been developed to be in line with the European Regulatory Framework, but since it promotes optimal assignment and use of spectrum, it is also valuable in other jurisdictions. Alternative methodologies to set extension fees in the situation described would involve either the development of business cases for other users or uses, or a benchmark of spectrum prices from auctions or secondary market transactions in other countries. In comparison, the methodology presented here is administratively less burdensome and less assumption-sensitive. It is flexible with respect to the extension period and the number of players in the market. When no auction outcome is available in the national market, outcomes from comparable markets could be used. However, this would yield a second-best estimate as it would require adjusting these outcomes as much as possible for all the differences in market and licence conditions (as in DotEcon, 2013).

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