Comments on

„Auction design proposals for the award of frequencies in the 700, 1500 and 2100 MHz bands“

(prepared by DotEcon Ltd for RTR)

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Preliminaries

In the above document (in the following the *Proposals*), DotEcon summarizes general recommendations for the award of frequencies in the 700, 1500, and 2100 MHz bands in Austria which is scheduled to start at the end of the first quarter of 2020. In our understanding these *Proposals* are based on suggestions by DotEcon which have previously been discussed with the RTR and to some extend incorporate a consolidated view of critical aspects of the forthcoming award.

The *Proposals* mainly present three alternative approaches for the award, one based on the simultaneous multiple round auction in a particular so-called simultaneous multiple round auction clock hybrid (SMRA Clock Hybrid, Model 1) and two combinatorial auction formats (Model 2) that are based on the combinatorial clock auction (CCA) on the one hand and a so-called combinatorial multiple round auction (CMRA) on the other hand. The *Proposals* also address the issue of awarding the spectrum in combination with rather demanding coverage obligations as well as a potential obligation to grant a *mobile virtual network operator* (MVNO) access to one's network.

Takon has been commissioned by the RTR to evaluate the *Proposals*. The RTR seeks in particular a second opinion regarding the selection of the respective approach (Model 1 vs. Model 2) as well as the activity rules and the information policies. Takon has also been asked to make suggestions for improving the designs. The main objectives, as communicated, are the efficiency of the allocation (which includes the aim to actually award all spectrum lots as well as the demanding coverage obligations) as well as supporting competition in the downstream markets (which includes provisions of a potential MVNO obligation). Generating public revenue is explicitly not a goal.

Our assessment (in the following *Review*) is compiled on the basis of (a preliminary draft of) DotEcon's *Proposals*, internal background presentations prepared by the RTR (in parts especially for this review project) as well as stakeholder statements made in response to a public invitation for comments (consultation). As the *Proposals* are intended to lay out possible *rough directions of the format of the award*, this *Review* not only assesses, but also builds on and complements the

[1] This document is a revised version of a draft of May 2019. Compared to the draft version, some spelling and grammatical mistakes have been corrected. The content and reasoning, however, is unchanged.

Proposals in terms of difficulties and potential solutions for actually implementing elements envisioned in the *Proposals*.

Takon and the authors of this *Review* personally know the authors of the DotEcon *Proposals* as well as some of the RTR employees involved from former projects. In fact, Takon and DotEcon have worked together on joint projects before. Moreover, during the evolution of this *Review*, the RTR has indicated which sections it wished to clarify or to further elaborate on. In this sense, the selection and weighting of topics reflects questions from and discussions with the RTR as the initiator and sponsor of this *Review*. However, neither DotEcon nor the RTR have given any guidance or indication of particular directions in which our assessment may potentially point. Apart from this, Takon is neither affiliated nor in contact with any potential bidder or other stakeholder in the forthcoming Austrian spectrum auction. All our comments, our evaluation and our recommendations have been independently developed and solely express the opinion of the authors of this *Review*.

Part A: Comments on the Envisioned Framework

1 Sharing Obligations and still Allowing for Synergies

The goals of the RTR for this award include far-reaching coverage obligations – particularly with respect to 700 MHz – which will be rather demanding for the successful bidders. Respondents in the consultation have expressed their desire to share the burden of extended coverage obligations among several *mobile network operators* (MNOs). At the same time, the structure of the obligations should still allow for a maximum of synergies.

The RTR plans to divide the obligations regarding 700 MHz into *basic obligations* on the one hand and *extended obligations* on the other hand. The basic obligations must be met by any winner of spectrum in this band. They ensure a high level of coverage by all spectrum holders and maintain competition among providers. The extended obligations enhance the coverage even further. In order to avoid wasteful duplication of these most expensive edges of the network, each of the extended obligations must be met by only one MNO. This significantly reduces total costs to society while, at the same time, providing almost full coverage of the country – provided that the extended obligations will be awarded.

Potential criteria along which the extended coverage obligations could be structured include a division into the types of the targets such as e.g. households, railways, highways and commercial areas. Obviously, however, in such a setup, there would be a lot of overlap of networks. Thus, an approach like this is not well suited to exploit synergies. More generally, if one MNO were to cover a geographical spot A and another MNO to cover a spot B in the neighborhood of A, both MNOs might need an additional base station which could possibly serve both, A and B. Thus, we recommend that any coverage obligation should refer to (or at least support covering) larger contiguous areas such as lists of groups of adjacent municipalities (up to, e.g., federal states), of which a certain proportion (measured e.g. in households, street kilometers, area …) are to be covered.

Efficiency, however, should not only relate to minimizing total costs to MNOs, but also a seamless service experience for consumers and third party service providers. This is particularly important for applications related to services, where continuous connectivity is required (e.g. in the area of traffic telematics). We recommend that if coverage obligations are assumed in exchange for financial rewards (regardless of whether these are actual payments or discounts), the respective providers should be obliged to grant competing MNOs as well as possibly MVNOs (in whatever way) access to their networks in those *areas relating to the coverage obligation for which they have received a financial benefit*. From an economic perspective, a negative price or a discount is a public subsidy. A provider who takes more obligations than its competitors should not be able to translate the subsidized coverage into a unique selling proposition. Note that it will be almost impossible for a competing MNO to catch up later in the respective areas without receiving at least similar subsidies. If it is easier for a strong MNO to fulfill the obligations, such an MNO may win more than an equal share. If there are no provisions for granting access, subsidized coverage obligations may lead to an even more concentrated market and eventually reduce competition.

A requirement to grant access relates particularly to pure coverage obligations (e.g. Stage 4 of Model 1 or Model 2 in the *Proposals*) or obligations that are awarded unevenly. It cannot easily be applied if coverage obligations are tied to multiple spectrum blocks (e.g. 700 MHz in Stage 1 of Model 1) without more or less neutralizing competition. We also admit that even for Stage 4 of Model 1 or Model 2, it may be a challenge to define the obligations in the way described above, to identify which geographical spot is covered by a subsidy, and to require that the recipients of the benefit grant seamless access in those areas. Still, we recommend exploring potential provisions for seamless connectivity.

2 Restriction of Non-negative Net Payments for Coverage Obligations

While the spectrum available for award is assumed to be highly valuable, the fulfillment of the coverage obligations is likely to be rather costly for an MNO and will, if being combined with the spectrum, significantly decrease the spectrum value. The RTR envisions that these costly coverage obligations do not have to be met by all Austrian MNOs. Rather it will be sufficient if each obligation is fulfilled by just one operator. Moreover, it should be possible that coverage obligations are shared. Thus, an obligation to provide service at a particular geographical spot must be met by at least one MNO, but different spots could be served by different MNOs.

Both models of the *Proposals* share the principle that the taker of an obligation might enjoy a discount on the price to be paid for the spectrum. The models differ, however, in the concise way in which the coverage obligations are structured as items in the auction and in the sequencing of their award.

In all approaches, a bidder's discount must not exceed the price for the spectrum won. I.e., in total the discounted price of a bidder must not be negative. We understand that this restriction is due to legal concerns and, thus, the rule simply ensures an implementation within the limitations of the legal framework. Very consistently, the *Proposals* take this limitation into consideration and both

models support this requirement. Still, we want to point out that this restriction may give rise to inefficiencies in the assignment and the use of spectrum.[2] The following examples illustrate the general problem and lay out the basis for the analysis of the different models. We will come back to this point in Section B.2 when comparing the two models.

Consider a spectrum auction where six homogeneous spectrum lots are auctioned among three MNOs, A, B, and C. For simplicity, let bidders be restricted to acquire at most three lots and assume a reserve price of 50. The bidders' marginal values of the first, second, and third block, respectively, are given in the following tables and are identical across the examples. Moreover, the regulator is aiming for one MNO to commit to assuming an extensive coverage obligation (CO) which is sold as a separate lot. The costs of fulfilling the CO for the three bidders are also shown in the tables. All examples are set up in a way that in an efficient allocation each bidder should obtain two spectrum lots and Bidder A should assume the CO.

Example 1:

		Bidder		
	Lot	**A**	**B**	**C**
Marginal Value	**1**	150	140	130
	2	110	100	90
	3	70	60	50
Cost of CO		-280	-290	-300

In the first example, the CO will *not be awarded*. As long as the price is below 70, the maximum discount for A when assuming the obligation is less than 3 x 70 = 210, and, thus, insufficient to cover the cost of meeting the obligation. If the price is above 70, then A will limit demand to at most two blocks which yield a maximum value of 260. In none of the cases A has an incentive to assume the CO. Note that with a reserve price of 50 per spectrum block and a reserve price for the CO of -300, an efficient allocation could easily be reached without net costs for the regulator, albeit with net payments to A. A would assume the CO and receive a net payment. B and C would pay positive prices that in total exceed the transfer to A.

Example 2:

		Bidder		
	Lot	**A**	**B**	**C**
Marginal Value	**1**	150	140	130
	2	110	100	90
	3	70	60	50
Cost of CO		-200	-250	-300

In Example 2, again, in an efficient allocation each MNO would acquire two spectrum lots. Moreover, the CO should be taken by A. A block based price system that supports such an outcome would need

[2] The problem is also mentioned in footnote 3 of the *Proposals*.

to price the spectrum lots between 70 and 90 and would need to offer a payment to the CO-taker between 250 and 200.

Note that if spectrum lots and the CO are auctioned as separate items without any restrictions on net payments, myopic (straightforward) bidding in both an SMRA Clock Hybrid[3] and a CMRA would yield this outcome.[4] Spectrum will sell at approximately 70 and the CO will be taken by A for a payment of approximately 250. Total surplus for the economy is 520 (including the public proceeds) plus the social value that the CO is awarded. Even though A receives a net payment of 250 – 2 x 70 = 110, the auctioneer collects in total proceeds of 6 x 70 – 250 = 170.

If no net payments to bidders are feasible, then – under straightforward bidding[5] – in both an SMRA Clock Hybrid and the CMRA all bidders will start bidding for three lots, but not for the coverage obligation. Only when the spectrum price reaches 67 per lot, A might start also to bid on the CO (the bidder may also wait longer if it is reluctant to reveal its costs relating to the obligation to either its competitors or the regulator). If, for some reason, the price reaches 90, then A would rather take three spectrum lots and the CO as opposed to only two lots and C would reduce demand to one lot rating. Thus, the auction would end at a price of 90 and A would be assigned three, B two, and C only one spectrum lot. The value to the economy would be lower and the market more concentrated than in the unrestricted case. Moreover, the CO subsidizes winning more spectrum for its taker. Interestingly, *lower efficiency* (which is due to the restriction of non-negative prices) *goes along with higher revenue and a more concentrated market* which contradicts the regulator's communicated goals for this award.

Example 3:

		Bidder		
	Lot	**A**	**B**	**C**
Marginal Value	**1**	150	140	130
	2	110	100	90
	3	70	60	50
Cost of CO 1		-110	-130	-160
Cost of CO 2		-90	-120	-140

Example 3 is identical to Example 2 with the only exception that the CO is divided into two separate COs. Here, one of the COs will be inefficiently taken by B as the possible additional discount for taking a second CO cannot be realized by A. Even worse, the restriction of no net payments to bidders not only involves the loss in efficiency as a cost to society, but also higher price discounts for the CO. Without the restriction, the discount to A would approximately be 250. Here, the total discount to A and B is about 300 based on the prices at which C quits bidding for a CO.

[3] The reference to an SMRA Clock Hybrid only relates to the auction format but not to Model 1 of the *Proposals* as in that model the obligations are tight to spectrum.

[4] In the example, actual unilateral demand reduction (i.e. an outcome where one bidder would accept one rather than two blocks) will not pay for any bidder. Of course, Bidder A could do better by giving up its third bidding right below a price of 70.

[5] In the CMRA we assume for simplicity that bidders only submit headline bids.

By increasing the costs of the COs for A and B, Example 3 can also be extended to the case where one of the two CO lots will not be awarded at all. The reason is similar to Example 1, but dividing the CO will exacerbate the problem. In other words, allowing operators to "share" the CO – here in combination with the no net payments restriction – may lead to inefficiently unassigned COs.

3 Bandwidth Requirements of Coverage Obligations

The *Proposals* do not yet indicate how coverage obligations will be specified. Typically, a coverage obligation sets out that a service must be available in a (certain proportion of a) region (defined e.g. as a particular area, certain households, commercial areas, traffic routes …) at a minimum bandwidth. From a technical perspective, the size and topology of the covered region as well as the type of the spectrum deployed (e.g. its frequency range) determine the costs of meeting the obligation whereas the amount of the available spectrum determines the speed of a communication channel and the capacity of the air-interface across the covered area. If coverage obligations include high bandwidth requirements, MNOs will also need a sufficiently large spectrum endowment. Thus, high bandwidth requirements may induce aggregation risks in the sense that an MNO bidding for a lot that carries a coverage obligation faces the risk of not being able to fulfill the bandwidth requirement if it fails to acquire sufficient spectrum. Therefore, an appropriately designed award procedure must ensure that a bidder assuming a coverage obligation will be able to make sure that it can acquire the necessary spectrum. This can be achieved, for example, by either bundling coverage obligations with sufficiently large chunks of spectrum (this is the approach of Model 1 in the *Proposals*) or by providing a combinatorial bidding language that allows bidders to package lots into large bundles by means of "and" and "xor" conjunctions (this is the approach of Model 2).

In broad terms, the 2100 MHz spectrum will be used to continuously run existing equipment. In the short and medium term, 3G use of the spectrum is likely to become re-farmed to 4G and possibly 5G in the longer run. The spectrum will also be used to provide additional capacity wherever it is needed. To a lesser extent, it will be used to expand the footprint of the network. In contrast, the 700 MHz spectrum – possibly augmented with an additional downlink layer in the 1500 SDL band – will mainly be used for expanding coverage as well as improving deep-indoor service.

We recommend eliminating to a large extent the aggregation risk associated with coverage obligations by basically requiring only 4G or 5G service. Bandwidth requirements will depend on the total amount of spectrum a bidder acquires. In the given case, the regulator should specify a table with downlink and uplink data rates depending on the amount of spectrum holdings in 700 and 1500 MHz.[6] For technical reasons uplink rates should only increase in the 700 MHz but not the 1500 MHz endowment.[7]

[6] The main rationale of requiring endogenous data rates is to mitigate the aggregation risk. It should be sufficient to specify downlink data rates only for endowments of at least 2 x 5 MHz and 2 x 10 MHz in 700 MHz both combined with and without 10 MHz in 1500 MHz. Uplink data rates will only depend on the endowment in 700 MHz (2 x 5 or 2 x 10 MHz). If the market demands higher data rates and a provider has more spectrum, it will be eager to provide the capacity.

[7] If the downlink reach of 1500 MHz (cell radius) will be significantly lower than the uplink range of a 700 MHz connection from a terminal to the base station, this difference could be taken into account when specifying the

We observe that in other countries or auctions frequency chunks smaller than 2 x 10 MHz were awarded in 700 MHz or other sub 1 GHz bands. Not requiring bidders to acquire at least 2 x 10 MHz in order to fulfill a coverage obligation will enhance flexibility and provide bidders with the option to select the business model that they believe will provide the highest value to their customers.

4 Design of the MVNO Obligation

Telecommunications markets are typically characterized by a small number of players operating own infrastructure. Moreover, market entry and exit are not frequent. In those markets, tacit collusion may evolve leading to providers focusing on different market segments, limited competition and rather high prices. One way of overcoming a potentially stagnating level of competition is to facilitate market entry through access or wholesale obligations. Thereby, it is not necessary that the new player invests in own infrastructure. However, the new player should be in a position to develop its own value proposition.

According to the plans of the RTR, which are reflected in the *Proposals*, an MVNO obligation should be assigned to promote competition in the downstream market. This means that it should foster the development of independent service offers as well as market entry by new players. We agree that an MVNO obligation is well suited to increase the level of competition. Since an MVNO's cost structure typically deviates from that of an MNO (an MVNO will have lower fixed costs and higher variable costs), it will be driven by different incentives when approaching the market. This makes tacit collusion with the established MNOs very difficult and highly unlikely. Thus, the mere existence of an MVNO is a benefit for society and justifies offering a discount to the provider taking the obligation.

In order to be effective, MVNO agreements should not be limited to very low volumes but allow for a sufficient market share of MVNO-based products that ensures a high level of competition.

MVNO access to an MNO's network may leverage sales efforts and increase network utilization. At the same time, however, it may also curtail the MNO's value chain and thereby de-value network investments. The latter may slow down an MNO's efforts to increase network coverage. This may hold in particular if access is granted on non-differentiated schemes which do not take quality characteristics of the service (i.e. speed or delay of data traffic) or costly rural vs. relatively cheap urban service provision into account. Thus, MVNO deals should foster new and innovative tariff systems that may evolve over time rather than restrict agreements to schemes designed in advance by the regulator.

The *Proposals* do not yet define how exactly an MVNO obligation may look. The basic requirement is that it should not be static but develop over time in order to reflect technological advancements, decreasing unit costs and changing customer behavior. Potential designs that were discussed in a kick-off meeting with the RTR included wholesale tariffs that are based on discounted retail prices.

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measurement conditions for the required data rates by appropriately relaxing the requirements for 1500 MHz at the cell borders.

We believe that MNOs will be rather reluctant to assume an MVNO obligation. This reluctance is greater the less clear the rules for MVNO agreements and the related potential business implications are. The feature of the design of the award is that the taker of the obligation will be granted a discount as an incentive to voluntarily accept the obligation. Moreover, competition in the auction should ensure that the obligation is awarded for the lowest cost.

In our view, defining ratios of retail to wholesale rates is not well suited for a voluntary obligation. The ratios may (i) either be too low (and thereby ineffective with respect to downstream competition) or (ii) they are too high and will give the MVNO an advantage over the MNO in the retail market. They will shift returns on investments undertaken by the MNO to the MVNO (which makes these investments less profitable and, thus, may decrease investment efforts). Even worse, an MNO might fear (whether this is justified or not) regulatory takings in the former case (i) in the sense that the regulator might re-adjust the ratios later, so that the MNO will end-up in the disadvantageous position (ii) in any case. Moreover, if the regulated tariff does not comply with a Ramsey-Boiteux tariff structure, a different tariff exists which is more advantageous for both the MNO and the MVNO. So, potential efficiency gains may be left unexploited.

We consider it to be crucial for an MVNO obligation to be assumed by an MNO on a voluntary basis, that the *business threats are clearly limited* and that these limits are relatively easy to estimate in advance. Moreover, the parties to an MVNO agreement should have maximum flexibility in designing their contract and the rules should make clear that regulatory takings are neither intended nor possible.

If an MVNO's market share of e.g. x% were sufficient to meet the regulator's goals regarding competition in the downstream market, this would relate to approximately 3-4 times x% of the traffic of one (possibly the smallest) of the three MNOs.[8] Therefore, we suggest that the taker of the MVNO obligation must commit to MVNO traffic in its network accounting for at least this minimum threshold.[9] The taker must present one or multiple contracts with one or multiple MVNOs within some time frame after the award (e.g. one year), each including a declaration of intent to reach traffic volumes that in total are not lower than the required threshold.[10] Moreover, the MNO must also present a default wholesale MVNO tariff that, in addition, grants any interested MVNO non-discriminatory access to its network. The prices of the default MVNO tariff must not exceed those in any of the presented contracts by more than e.g. *y*% based on the basket of intended traffic volumes.[11]

[8] Market shares of the MNOs in Austria range between approximately 25% and 45%.

[9] Traffic could be measured in units consumed, i.e. GB of data in relevant service quality categories as well as possibly voice minutes. Another possibility that would be much easier to administer could refer to a certain fraction of service revenues. Note that the latter might distort incentives towards setting higher prices.

[10] There could be the rule that the discount will only be paid out after showing proof of the MVNO contracts and the respective intentions of traffic volume.

[11] The default tariff should not include fixed cost components not related to traffic or the number of customers. Actual contracts, however, may have such components. Thus, an MVNO obligation may also help an MNO to finance coverage improvements. A taker of the default tariff may re-negotiate its conditions with the MNO on a commercial basis at any time. This is important to allow for efficiency gains from *two-part tariffs* avoiding *double-marginalization*.

The taker of the MVNO obligation will have to show proof of reaching the required MVNO traffic on a regular basis. If the required threshold volume is not reached, the MNO will be required to lower its default tariff such that the total costs of a basket of wholesale services weighted based on actual (or intended) volumes will decrease by a given minimum rate. Apart from this, the MNO is free to design its wholesale tariff structure. This allows for second-best prices e.g. in line with the Ramsey-Boiteux principle. Contracts closed on a commercial basis remain untouched. However, an MVNO may always opt for switching to the default tariff. In order to limit the impact of the MVNO obligation, the MNO might be given the right to raise its default MVNO wholesale tariff if MVNO traffic exceeds an upper threshold.

Part B: Comments on the *Proposals*

1 General Comments

We consider the *Proposals* to be carefully designed with respect to the situation in Austria and the goals of the regulator. The DotEcon paper presents the goals of the regulator precisely as they were communicated to us and effectively takes existing constraints into account. Among these constraints is the requirement discussed above that the total spectrum price for a bidder after discounting for assuming any obligations must not be negative.

The main feature of the *Proposals* is that two alternative models are presented. The first one (Model 1) leverages the *value of the spectrum* in order to incentivize MNOs to assume coverage obligations. The right to use the spectrum is tied to the requirement of a minimum reach of the network. We agree that the value of the spectrum is a strong incentive for an MNO to accept obligations in exchange for being allowed to use the spectrum. We also support the rationale of the *Proposals* that, if coverage obligations are tied to specific spectrum blocks, the interdependencies between blocks are manageable and that a relatively simple simultaneous multiple round auction will be appropriate for auctioning these items. The proposed clock variant, the SMRA Clock Hybrid is a well-suited design to speed up the auction process significantly and to limit the scope for collusion that could be achieved by exchanging messages over multiple rounds.

Somewhat uncommon is the proposal of Model 1 to separate the award of 700 MHz and 2100 MHz on the one hand and 1500 MHz on the other into two consecutive stages. However, we completely agree with this approach. Since the value of 1500 MHz strongly depends on the endowment with 700 MHz there needs to be certainty of this endowment when bidding for 1500 MHz. The proposed sequential procedure provides the required certainty and avoids the respective aggregation risk. As the dependency is significantly lower the other way round, the sequencing adequately addresses a problem that otherwise only a combinatorial approach could solve.

Since the envisioned coverage obligations are assumed to be highly demanding, there might be the risk that all or some spectrum lots will not be sold or that not all interested MNOs may bid for spectrum. This is the case if the cost of fulfilling the coverage obligation exceeds the value of the spectrum. Due to different existing spectrum holdings and differences in the footprint of the current

network, the burden of accepting an obligation might differ among the bidders. Even if only one or two of the bidders were unable to fulfill the obligations linked to one or several of the spectrum lots, these lots may remain unsold[12] and even if they are sold, competition might be low so that the price that society pays for the obligations to be taken can be rather high. Since, in fact, the risk that the envisioned coverage obligations will be too demanding for at least one operator is not negligible, the *Proposals* recommend to somewhat relax the coverage requirements tied to spectrum (*specific obligations*, see Section B.3 for details) in order to ensure that they can be achieved by all MNOs. The remaining obligations (*additional obligations*, ibid.) are then to be packaged into additional lots which will be sold in a separate later stage (Stage 4) possibly for a negative price that will be credited against other liabilities payable from the auction. The detachment of obligations from particular spectrum lots may allow outcomes in which an otherwise unsold lot (consisting of both, spectrum and a coverage obligation) will now be awarded and only parts of the obligation may remain unsold.[13] Thus, dividing the coverage obligation into components that will be awarded in Stage 1 and others that will be awarded in Stage 4 effectively addresses concerns of unsold spectrum and untaken coverage obligations. The separation of the coverage obligations has the additional advantage that, in principle, another bidder who faces lower costs associated with the obligation and who for some reason does not have the intention to bid for more spectrum[14] may take the obligation in exchange for a larger discount on its total price. All this will increase overall efficiency.

Model 2 elaborates on this idea even further. In this model, only *basic obligations* remain tied to spectrum lots and the more ambitious *extended obligations* are sold as separate lots. The underlying rationale is that the costs of fulfilling obligations will differ among the MNOs. Moreover, if an MNO has a cost advantage over a competitor with respect to some coverage obligations, it will be likely that this MNO will have a similar advantage on other obligations. Thus, the separation of coverage obligations from spectrum lots will allow for efficiency gains arising from a more asymmetric allocation of obligations than is desired for the allocation of spectrum.

Since the costs relating to coverage obligations may strongly depend on the spectrum endowment (particularly the award in the 700 MHz band, possibly augmented with 1500 MHz), the *Proposals* recommend – in our view consequently – a combinatorial auction for this case.

2 Combinatorial Auction Format in Model 2

Any combinatorial auction format comes with some weaknesses. In the given situation, however, we clearly favor the CMRA over the CCA. Among the major drawbacks of the CCA in a spectrum auction context are its second-price principle, the incentive to raise competitors' prices in the supplementary stage, and the risk for bidders to leave the auction empty handed.

[12] This holds in particular if effective spectrum caps are in place.

[13] Note that the additional obligations may well be sold even if a spectrum lot carrying the full obligations were not sold in Stage 1 because in Stage 4, obligations can be subsidized by a discount credited against liabilities from spectrum bought in 2100 and 1500 MHz.

[14] There are several possible reasons why a bidder might not bid for additional spectrum to which an obligation is tied even though it can fulfill the obligation at rather low costs: it may not need the spectrum, it may be capped to bid for more lots, or a larger (typically more asymmetric) endowment might simply be less efficient.

In a spectrum auction, bidders' budgets are typically smaller than their business case values. However, for the CCA to yield an efficient outcome, bids should reflect the true values of the respective packages. Due to the second-price principle, the necessary budgets can significantly exceed the prices bidders actually would have to pay in the efficient outcome – if such an outcome were reached. If one or more bidders are not able to submit bids in the range of their values, then efficiency of the resulting outcome is no longer a property of CCA. Note that if a bidder is budget-constrained with respect to some of its bids, it may adjust all other bids as well in order to maintain some consistency among his bids and not to outbid one of its own bids on a larger package by a smaller one.

The CCA's core pricing rule – in terms of potential discounts – gives incentives to bidders to raise their rivals' costs. This holds in particular for the supplementary stage. Since these incentives are offered to all bidders, the prices typically increase significantly in this stage. Due to the relative caps, however, for a large range of values, the probability that the intermediate outcome of the clock stage will change in the supplementary stage is rather low. In this case, only the revenues of the auctioneer increase. Problematic from a theoretical perspective is the fact that the incentive for bidders tends towards lower efficiency: bidders can profit by increasing bids for packages they will not win and decreasing bids for packages they would win in the efficient allocation. The problem is amplified by (possibly even asymmetric) budget constraints. Thus, if the allocation will change in the supplementary stage, efficiency will not necessarily increase but may potentially decrease. Bidders even face the risk to leave the auction empty handed without the possibility to appropriately react in time. In that case, revenues would increase for no gains or possibly even losses in efficiency. This contradicts the goals of the regulator.

The CMRA addresses the above problems by applying a pay-as-bid rule rather than a second-price scheme. This means that bidders only need to have budgets in the range of the prices they will eventually pay. By means of the additional bids that bidders feed in during the process of the auction, they explicitly indicate alternative outcomes that they would agree to rather than manipulating prices of competitors. And, finally, a bidder will never leave the auction empty-handed if it has not explicitly submitted a zero bid at given clock prices.[15]

A feature that we consider a disadvantage of the CMRA is that it might give stronger (perceived) incentives for demand reduction and is likely to lead to more differentiated prices. To see this, consider an auction with three bidders where six homogeneous items are sold.[16] Assume that in a particular round t, lot prices are p_t and the auction has not yet ended. Let the excess demand in an SMRA Clock Hybrid be e. Then a bidder with activity a must decide whether to continue bidding (with some unknown outcome of a bundle not exceeding a lot ratings and lot prices above p_t) or to possibly end the auction. The latter will yield a payoff of $v(a - e) - (a - e) * p_t$ ($v(x)$ denotes the value of a bundle with x lot ratings) and all bidders will pay (up to one increment) the same price. If the headline bids in a CMRA were identical to the demands in the SMRA Clock Hybrid, the same bid could

[15] Note, however, that even if a bidder submits a zero-bid, it may eventually become awarded an additional bid that it submitted earlier.

[16] We are very thankful for a fruitful email discussion with DotEcon on the characteristics of the CMRA. Any remaining errors, however, are ours.

also end the CMRA and the outcome would be identical. The prices for the considered bidder, however, can be (much) lower. This is the case if the bidder repeats its headline bid and submits in addition a respective additional bid at a lower price. In fact, the prices for this bidder can be as low as the reserve prices. Note that by this bid, the bidder does not win the smaller package with certainty nor will it end the auction with certainty and pay a low price. Still, the bidder can explore these opportunities. Moreover, if the other bidders have in total reduced the activity of their headline bids below total supply in a prior round, a possibility to close the auction at prices that for this bidder are lower than the prices in the corresponding SMRA Clock Hybrid is guaranteed to exist. Depending on the information policy it may be more or less tricky to identify this option. One strategy to tacitly explore potential low price outcomes might be to submit in the first round – in addition to an ambitious headline bid – a list of outcomes that were acceptable if they were available at the reserve price.

One can argue that the possibility of ending the auction by reducing demand and then pay a relatively low price might incentivize bidders to bid longer on larger packages and to step back to reducing demand at a later point in time if the auction had not ended by then. Since, however, there is no guarantee that the bidder will be able to win the bundle at a similarly low price, the incentive might not be very large. In any case, it is likely that the auction ends with a combination of headline and additional bids (which can be below current round prices). Thus, prices might be highly diverse and revenue can be low.

A practical problem arises from the question when bidders will start bidding on obligation lots. This will not be before the total price of a package without an obligation exceeds the obligation's costs. But even if the effective discount will be as large as the cost of the obligation, a bidder might not start to bid on the obligation immediately (cf. Section A.2). The auction could then end before a bidder had started to bid on an obligation. A simple means to fix this is to require at least two consecutive stationary rounds before the auction closes.

3 Comparison of Model 1 and Model 2

Both, Model 1 and Model 2, have their strengths and are generally suited to be applied in the forthcoming spectrum award in Austria. The biggest advantage of Model 1 is that it leverages the value of the spectrum to invite MNOs to accept coverage obligations. Moreover, both the auction format and the linkage of obligations to spectrum are well established and transparent procedures. The main advantage of Model 2 (at least at first glance, see discussion below) is its higher efficiency that comes with the flexibility for bidders to acquire spectrum and coverage obligations in different proportions. Both models, however, come also with weaknesses that we will try to lay out below. We will also discuss means to mitigate disadvantages whenever possible.

The *Proposals* foresee for Model 1 rather large lots of 2 x 10 MHz in the 700 MHz band. Given these caps, there are only few possibilities left for an allocation and some of these possibilities are highly unlikely. With three bidders and three lots, a uniform allocation with one lot for each bidder is a natural focus point. On the one hand, therefore, strategic demand reduction is rather likely. If the uniform allocation is not efficient, the design will then invite an inefficient outcome. Moreover, low prices of this valuable spectrum will make the additional coverage and the MVNO obligations, which

will be awarded in Stage 4, less attractive as bidders cannot receive sufficiently large discounts on their total bill in exchange for taking obligations. On the other hand, if the auction does not result in a uniform allocation, the larger provider will have a significant advantage and the market may become more concentrated.

The reason for the large lots is to mitigate the aggregation risk that may come with the coverage obligations if they require large bandwidths. We understand that ensuring spectrum of at least 2 x 10 MHz also addresses the articulated needs of the MNOs. Their desire is two-fold: Firstly, if a far-reaching coverage obligation also requires demanding minimum data rates, then a minimum spectrum endowment is required to fulfill the obligation. Secondly, expanding the footprint of the existing network incurs significant fixed costs. To recover at least some of these costs, MNOs seek to enable sufficiently high traffic volumes.

We recommend tackling the problem from the other end. Firstly, we seek to eliminate the aggregation risk that may be associated with strict bandwidth requirements by relaxing those requirements and making them dependent on the amount of spectrum actually acquired in the auction (cf. A.3). Secondly, we suggest minimizing the burden relating to the costs of fulfilling the obligation by restricting its geographical extension. According to our alternative proposal, the risk of getting stranded with only one 2 x 5 MHz block in 700 MHz relates to the burden of fulfilling the specific obligations in only about 1/6 of Austria. This lower burden should make the spectrum attractive also for a rather weak MNO who potentially faces large costs to fulfill the obligations. An MNO that is reluctant to accept onerous obligations may then choose to take only a relatively small one while still being allowed to deploy the spectrum nationwide. In combination with e.g. 1500 MHz or other bands this will nevertheless support rather attractive service offers. Overall, we believe that chunks of 2 x 5 MHz will provide more flexibility and allow for potentially greater efficiency. In combination with the relaxed activity rule suggested in Section B.4, the aggregation risk is further mitigated as the combination of smaller lots in 700 MHz and the relaxed activity rule allows exploring alternative business models in the auction. With larger lots, bidders would have to make far-reaching and irreversible decisions earlier in the auction. Further, due to the possibility of somewhat asymmetric outcomes, demand reduction is less obvious. Thus, there is a higher probability of competition for these blocks which, in turn, will increase the effectiveness of the incentives for assuming a coverage or MVNO obligation in Stage 4.

If the costs relating to the coverage obligations attached to the individual lots are very different, then MNOs will first bid on the lots with the “easiest” obligations. Their price is expected to increase until the MNO who systematically has the lowest costs of fulfilling the obligations switches to other lots. In the end, lots with the most demanding obligations will be awarded to the strongest bidder for the lowest price, possibly the reserve price. On the one hand, this in turn will increase the incentive for a weaker bidder to bid for coverage obligations in Stage 4 as they have the opportunity for larger discounts. On the other hand, the incentives for the strong bidders (i.e. those MNOs that should take the obligations in an efficient outcome) decrease. Moreover, if asymmetries are strong, there will be the risk that a weaker bidder might quit bidding on 700 MHz before a stronger bidder shifts demand to more “difficult” lots. This induces the risk of unsold lots including the attached coverage obligations. Thus, we recommend to structure lots in a way such that the expected costs related to fulfilling the obligations are rather similar.

It was mentioned above (cf. Section B.1), that a general disadvantage of tying obligations to spectrum (as it is proposed for the assignment of the spectrum in Stage 1 of Model 1) is the fact that it forces MNOs to accept coverage obligations in the same proportions as they acquire spectrum. This means that an MNO who acquires twice as much spectrum as a competitor has to accept approximately two times the burden of the attached obligations. If tight coverage obligations were particularly costly for one of the MNOs, this MNO might not be able to compete and could ultimately not win any of the valuable spectrum. If, to the contrary, an MNO had a cost advantage over a competitor in fulfilling the obligations, then the coverage obligations will implicitly subsidize this MNO in acquiring more spectrum than its efficient share in spectrum.[17] This is because MNOs partly pay for the spectrum with meeting the coverage obligations. These costs can be lower for a stronger MNO who might then acquire more spectrum even if the spectrum as such had the same value for all bidders. The argument can also be flipped around: if the goal were to minimize total costs to fulfill the obligations and some strong bidder had a systematic cost advantage over its competitors, then the cap on spectrum might prevent an efficient award of the obligations. To some extent, the argument carries over to the obligations auctioned in Stage 4: if an MNO expects to win also (some) additional obligations in that stage, it might be willing to pay more for spectrum in Stage 1 because the discount will offset the price.

In Section A.2, however, it was shown that the restriction of no net-payments can have a similar effect in Model 2 as it may strengthen the market position of strong bidders even further. Thus, given this restriction, the combinatorial approach of Model 2 cannot completely exploit its theoretical advantage.

The fact that in Model 1 coverage obligations are tied to spectrum makes this model on the one hand somewhat less vulnerable to the distortions of the no-net payments restriction. On the other hand, if the costs related to an obligation are in the range of, or above, the value of the spectrum, they could lead to unsold spectrum rather than only unassigned obligations (as would be the outcome in this case in Model 2). The *Proposals* recommend minimizing this risk of the model by somewhat relaxing the obligations that are attached to the spectrum lots in Stage 1, the so-called *specific obligations*. The differential of the targeted obligations and the specific obligations tied to spectrum will then be awarded in the separate Stage 4 in so-called *additional obligation* lots. The split should be such that the specific obligations in Stage 1 are as demanding as possible, limited only by the requirement that even the weakest bidder should be able to fulfill any of the specific obligations attached to a spectrum block. We agree with this assessment. If an MNO were not able to meet the obligations, competition for the spectrum would not be possible, the price might be low and the discount offered for taking the remaining obligations in Stage 4 could not become an effective incentive owing to the no-negative price restriction.[18] The main driver for awarding the obligations in Model 1, though, is

[17] In this context, "efficient share" refers to the share of spectrum that the bidder would acquire in an efficient outcome of a pure spectrum auction without considering coverage obligations.

[18] If a relatively weak MNO were able to fulfill some, but not all of the specific obligations, the disadvantages of asymmetric specific obligations discussed above would be amplified. For example, a strong bidder could acquire uncontested blocks for the reserve price. This MNO bidder might be best-suited to take respective additional obligations, too. Due to the no-negative price restriction, however, it might not have an incentive to do so.

the value of the spectrum. So, the design should leverage this value to the largest extent possible. There is a non-negligible risk that the additional obligations in Stage 4 might remain unawarded. This risk is lower the smaller the burden associated with the additional obligations. This, again, calls for specific obligations in Stage 1 that are as strict as possible.

Given our recommendation that the obligations should refer to rather large contiguous regions (cf. Section A.1), there will be economies of scale or scope if the additional obligations of Stage 4 again specify concise geographic areas. The disadvantage of this approach is that competition for obligations in Stage 4 will then be very limited (if it will exist at all) since the synergies between obligations of Stage 1 and Stage 4 are specific to individual bidders and, consequently, valuations are quite diverse. If the obligations will be awarded, this will be rather expensive for society. To eliminate this problem, we suggest designing the coverage obligations for Stage 4 in a manner as generic as possible. This means that they should abstractly refer to additional households, street kilometers, number of villages or simply the size of an area.[19] Preferably, these obligations will also be homogeneous which allows bidders simply to bid for a certain number of obligations. This will open a level playing field for competition.

Whereas the *Proposals* "do not expect synergies from taking on different [coverage obligations]", we tend to believe the opposite in the sense that bidders might be restricted (e.g. by planning resources or budget) in taking on too many obligations. So, a bidder may be willing to accept some, but not all coverage obligations. Moreover, the total amount of the bids is limited by the maximum discount of the bidder. A bidder will have to decide on how many and possibly which lots to split the available resources. This is quite a complex coordination problem that a relatively simple first-price sealed-bid auction cannot adequately solve. We would rather recommend deploying a combinatorial first-price sealed-bid auction. The challenge will be easier the more obligations are homogeneous as this would allow for an SMRA Clock Hybrid or even a sealed pay-as-bid multi-unit auction.

The MVNO package carries some external effects in the sense that to some extent the increased competition in the downstream market might also affect the profits of other MNOs. Thus, in an open auction, MNOs might adopt a strategy of avoiding to bid on the MVNO lot as long as no other MNO bids on it. Competition only starts after the first bid has been submitted. Thus, the open procedure of the CMRA will invite tacit collusion. This risk can, in our view without disadvantage, be eliminated by auctioning the MVNO lot in a separate stage by means of a first-price sealed-bid auction.

A further disadvantage of Model 2 is that the combinatorial auction formats are much more complicated than the proposed SMRA Clock Hybrid in Model 1.

We conclude that in an implementation that closely follows the design of the *Proposals*, we slightly favor Model 2 over Model 1. However, we believe that the disadvantages of Model 1 can be mitigated. If at least 2) (in combination with 1)) or 4) of the points below regarding Model 1 can be addressed, the order of our preference will reverse.

[19] There should be accompanying rules which would govern application procedures for registering planned fulfillment of obligations as well as penalties for failing to comply. Owners of Stage 1 obligations might be granted priority for some time before others can register for fulfilment of obligations in "their" regions.

In sum, our recommendations for Model 1 – if being chosen – are:

1) Relax aggregation risks by making bandwidth requirements of coverage obligations dependent on the amount of spectrum acquired in the 700 MHz and 1500 MHz band (cf. A.3).
2) Structure lots in 700 MHz in chunks of 2 x 5 MHz rather than 2 x 10 MHz each and attach to each lot (disjunct) coverage obligations.
3) The burden of the coverage obligation should be roughly similar. Asymmetries will increase public revenues (and thereby increase the probability that the additional obligations in Stage 4 will be awarded) but at the same time increase the risk of unsold lots in Stage 1.
4) Define the additional coverage obligations in Stage 4 generically, i.e. in an abstract, preferably homogeneous way, so that synergies between obligations in Stage 1 and Stage 4 are not specific to individual bidders.
5) If coverage obligations are homogeneous, auction them in Stage 4 by a pay-as-bid multi-unit auction. The reserve price may be kept secret.
6) If some, but not all coverage obligations are homogeneous, run an SMRA Clock Hybrid for the coverage obligations. Reveal reserve prices.
7) If coverage obligations are heterogeneous, run a first-price sealed-bid combinatorial auction. Reserve prices may be kept secret. The prices of the pairwise disjunct package bids of an MNO are limited to its current payment liability, i.e. its maximum discount. Alternatively, the principle of an SMRA Clock Hybrid could be considered even though there are no clocks, but only individual prices.
8) Auction the MVNO obligation separate from the coverage obligations in a first-price sealed-bid auction. The reserve price may be kept secret.

Our recommendations for Model 2 – if being chosen – are:

1) Require two consecutive stationary rounds before the CMRA closes.
2) Do not auction the MVNO obligation in the combinatorial auction. Conduct a separate stage and run a first-price sealed-bid auction to award this lot.
3) If auctioned in a separate stage, the reserve price of the MVNO obligation may be kept secret.

4 Activity Rule in the SMRA Clock Hybrid (Model 1)

We consider it important that bidders will have the opportunity to switch from one band to some other band and switch back to the original band if the development of the relative prices suggests such a move.[20] Since for technical reasons spectrum cannot be substituted exactly in relation to the

[20] A benchmark in the context of this analysis is myopic or straightforward truthful bidding and the efficiency of the resulting allocation. Against this background, we argue that straightforward truthful bidding should allow for an efficient outcome. Note that if spectrum lots of different bands are, to some extent, substitutes, then a bidder might switch from one band to the other if the prices in the band where it was bidding have increased, but the other band had temporarily settled. Switching bands may then cause the price dynamics to reverse so that this bidder might want to switch back in a later round. The bidder should not be forced to reduce demand over this cycle.

lot ratings, we recommend to relax the activity rule in order to avoid that a bidder will lose eligibility when switching from one band A to another band B and switching back some rounds later in response to a price increase of band B.

The proposed system of lot ratings allows substituting two blocks in 2100 MHz with exactly one block in 700 MHz (given 2 x 5 MHz chunks) and vice versa (rate of substation of 2:1). We recommend a more relaxed rate of substitution and propose that a bidder's eligibility in round t+1 will be set to min{e, a+1} lot ratings if the bidder in round t had an eligibility of e and exercised an activity of a lot ratings. Given that this bidder was initially granted an eligibility exceeding its most optimistic targets by 1, throughout the auction this bidder can substitute up to one block in 2100 MHz by one block in 700 MHz (1:1) or, in the other extreme, three blocks in 2100 MHz by one block in 700 MHz (3:1), and it can also reverse these substitutions without losing eligibility. A bidder, aiming for n lots of 2 x 5 MHz in 700 and m lots of 2 x 5 MHz in 2100 MHz has an activity of 2 n + m lot ratings. With the relaxed activity rule, this bidder could switch between the preferred allocation and an alternative business model with (n-1) lots in 700 MHz and (m+1) lots in 2100 MHz without losing eligibility. If the bidder had an eligibility of 2 n + m + 1, it could also explore alternative outcomes with (n+1) and (m-1) or (n-1) and (m+3) lots in the respective bands. Note that the relaxed activity rule does not allow for alternating between more diverse business models. A bidder switching, e.g. from 3 lots in 700 MHz and 2 lots in 2100 MHz to 1 lot in 700 MHz and 4 lots in 2100 MHz would lose eligibility and will not be able to switch back. Alternating between, e.g. 3/2 and 1/5 lots in the respective bands, however, would be possible.

We agree with the *Proposals* that provisions for withdrawals are not necessary. Moreover, the ranking of bidders (as opposed to ranking of bids) in each band in order to determine provisional bidders is a smart feature that does not discriminate any bidder on a systematic basis. The proposed auction format will proceed at sufficient speed and block prices will differ by at most one increment. The auction format even allows for uniform pricing which we would believe will further increase the acceptance of the format by the industry.

1) If the 700 MHz spectrum is auctioned in 2 x 5 MHz chunks, relax the activity rule so that (at least in an early stage of the auction), a bidder with an eligibility of e lot ratings and an activity of a lot ratings in some round t will have an eligibility of min{e, a+1} lot ratings in round t+1.
2) If the 700 MHz spectrum is auctioned in 2 x 10 MHz chunks a more relaxed activity rule should be considered.
3) Consider the uniform pricing rule presented in the *Proposals*.

5 Information Policy

Business models of MNOs do not only depend on own spectrum holdings but, to some extent, also on the allocation of spectrum among all providers or, at least, their own relative market position. Therefore, MNOs are strongly interested in the relative demand in the various bands as well as in the individual demand of each bidder. Note that the revelation of information is the main advantage of running a dynamic auction. The theoretical marvel of revealing information stems from the fact that

in case of value uncertainties it helps bidders to assess more precisely the actual value of the spectrum and thereby reduces the risk of the winner's curse.

Assume there were only one class of homogeneous items as it is the case in Stage 2 of Model 1. Then a clock auction without revealing more information than the forward ticking price is equivalent to a sealed bid auction in which bidders submit schedules in the form of (price, quantity)-pairs. The quantity a bidder demands at a particular price in the sealed bid auction is exactly the same quantity demanded in a clock auction at this price given that the auction had not yet closed.[21] Thus, the open auction would not take advantage of its open format and could, from a theoretical perspective, be replaced by a sealed bid format.

In a multi-product clock auction, the increasing clock prices reveal slightly more information (this is the case if one price clock stops, but the other continues). Thus, the above argument does not apply in its strict form to Stage 1 of Model 1 of the *Proposals*. Moreover, any information provided may give bidders the possibility to exchange implicit messages that could potentially facilitate tacit collusion or even demand reduction that may lead to low-price outcomes with inefficient allocations. This holds more strongly the more information is provided. However, we believe that this risk is rather low or even non-existent when revealing only aggregate demand at given clock prices for each item class. Thus, we recommend providing this information as it will help bidders to assess current auction situations. Moreover, a peculiarity of the SMRA Clock Hybrid is that if aggregate demand is not fully disclosed and only one bidder is randomly selected and partially awarded in each band, this bidder has an asymmetric information advantage. This asymmetry can be resolved by publishing at least aggregate demand in each round to all bidders.

The problem is somewhat more difficult regarding whether to provide e.g. full information with respect to all bids. On the one hand, several spectrum auctions (e.g. in Germany) have shown that providing this information will not necessarily lead to low price outcomes. On the other hand, auctions with full information revelation have resulted in such outcomes in Austria in the past.[22] Thus, a more defensive policy with respect to providing all information might be considered.

In the CMRA, the main information is captured in the headline bids. These bids should represent the preferred option given the current round prices and, thus, provide valuable and sufficient information to the bidders. Additional bids state second-best alternatives and might also be used for strategic purposes. We consider this information less valuable. Moreover, information on additional bids can be strategically exploited for particular closing scenarios. Note that by the observable information which prices tick forward, bidders may be able to deduce some more information than the headline bids alone will provide.

Our recommendations for the SMRA Clock Hybrid (Stage 1 and Stage 2 of Model 1) are:

[21] The proof follows from the revelation principle. Assume each bidder would delegate bidding to an agent. If in the auction nothing is revealed but the clock price, the agent can only be instructed to bid for particular quantities depending on the price. If there is nothing else the agent can observe or possibly react to, a sealed-bid auction can be implemented in a way that it simply takes the instructions to all agents and yield the same result in terms of quantities and prices as the open auction.

[22] This does not mean that the outcome is due to demand reduction based on the information provided, nor is a low price outcome a proof of inefficiency.

1) Reveal the reserve prices of all lots auctioned in the SMRA Clock Hybrid.
2) Disclose at least the aggregate demand for each band in each round. Revealing full information on the demand of each bidder in each band might be considered, but the associated risk of demand reduction should be carefully assessed.

Our recommendations for the CMRA (Model 2) are:

1) Reveal the reserve prices of all lots auctioned in the CMRA including the coverage obligations.
2) Reveal at least aggregate demand of headline bids. Revealing all headline bids in all bands might be considered, but the associated risk of demand reduction should be carefully assessed.
3) Do not reveal additional bids.