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The 5G spectrum auction in Chile

Juan Escobar [a], Rafael Epstein [a], Jose Correa [a], Pamela Gidi [b], Jozsef Markovits [b], Natalie Epstein [a,c,*], Yerko Montenegro [d], Abner Turkieltaub [e]

[a] Departamento de Ingenieria Industrial, Universidad de Chile, Chile
[b] Ministerio de Transporte y Telecomunicaciones, Gobierno de Chile, Chile
[c] Harvard Business School, Harvard University, United States of America
[d] Ministerio de Hacienda, Direccion de Presupuesto, Gobierno de Chile, Chile
[e] Department of Computer Science, University of British Columbia, Canada

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ABSTRACT

In 2021, the Chilean government implemented a first-price package auction to allocate electromagnetic spectrum for 5G mobile services. The auction was run sequentially for different spectrum bands, allowing firms to exploit band complementarities. It was a combinatorial auction, so firms could bid for any combination of blocks within a band. It contemplated spectrum caps – upper limits on the spectrum for each firm – to ensure competitiveness. The beauty contests used in previous processes became obsolete, as there was a need to promote competitiveness and transparency in the telecommunication sector. Four incumbents and one potential entrant participated in the auction. The auction raised more than USD $450 million, which was six times more than the sum of the revenues of all previous contests in the country. We discuss this experience and show how different aspects of the context justified our design choices.

1. Introduction

The allocation of electromagnetic spectrum for mobile services is a critical component of modern telecommunications infrastructure. In Chile, the traditional method for assigning spectrum was through beauty contests, where companies submitted technical projects and spectrum was assigned based on coverage and quality of the proposals. However, beauty contests are uncompetitive and lack transparency (Prat & Valletti, 2001). While some incumbent companies argued that beauty contests promoted investments in socially valuable telecommunication networks, in 2018 the digital divide in Chile was significant (SUBTEL, 2019). As a result, in 2018, the Chilean government faced the challenge of rethinking the method for assigning spectrum, especially for the upcoming 5G mobile services.

The assignment process for 5G mobile services was a big opportunity for the Chilean government. A recurrent concern in the previous assignment processes organized by Subtel was the existence of red zones with little to none fixed broadband penetration. The assignment process for 5G spectrum provided a new chance to address this digital divide (Cave & Nicholls, 2017).

Moreover, 5G also delivers high download speeds and lower latency, which make possible the development of new applications in the Internet of Things (IoT), automation and augmented reality (Cave, 2018). Since productivity growth in Chile has been lagging behind for years, the implementation of the 5G technology seemed like a natural boost to the telecommunication sector (Rao & Prasad, 2018). For instance, mining (minerals and metals) and agriculture are the two major export industries in Chile (46 ad 31%

* Corresponding author at: Harvard Business School, Harvard University, United States of America.
E-mail address: nepstein@hbs.edu (N. Epstein).

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Table 1
Normalized revenues per country for the 700 MHz band.

Country	Year	USD/MHz - Pop
Chile	2014	0.02
Brazil	2014	0.13
Germany	2015	0.18
Peru	2016	0.32
Italy	2018	0.51
France	2015	0.63

of exports, according to The Growth Lab, 2020). Increasing productivity in these industries is key, and the main enablers are digital transformations that incorporate new technologies and process automation. It was then crucial to design a process to assign 5G spectrum efficiently.

In this paper, we report some of the main technical and regulatory challenges of the first spectrum auction in Chile. We designed a first-price package auction that took place in February 2021 and assigned spectrum in the bands 700 MHz, AWS (1700 and 2100 MHz) and 3.5 GHz. Four incumbents and one potential entrant participated in the process. The auction raised more than five times the sum of all revenues obtained in previous assignment processes. We discuss and draw lessons about how the Chilean context determined some of the design choices. While bringing competition to spectrum assignment was resisted by some, the whole process has been welcomed by the media and policy experts.

2. Antecedents

2.1. Beauty contests in Chile

Before the 5G auction, spectrum allocation in Chile had always been performed through what is called a beauty contest. A beauty contest is an administrative process that allocates spectrum based on a company's technical project to develop infrastructure and provide mobile services. Companies would submit technical projects. Those projects received scores according to a well-defined criterion, including geographical coverage, service quality, and the time frame of the network deployment.

Oftentimes, companies would tie in their technical proposals. According to the law, in those events spectrum would be assigned in a second stage using a tie-breaking auction. While this second stage could indeed introduce competition for spectrum, in practice, it did not.

Two were the main drawbacks of the old process used to assign spectrum in Chile. The first one was its lack of transparency. While firms could commit to making substantive investments in isolated red zones, it was hard to monitor those investments. Moreover, it was not clear whether some of the investments firms committed to in their technical projects were socially but not privately beneficial or, on the contrary, were part of their main business strategies. It was hard to even assess the non-monetary contributions that mobile companies were making to the Chilean state for the use of electromagnetic spectrum.

The second main drawback that the process had relates to the tie-breaking auction. In theory, these auctions would decide winners according to their revealed willingness to pay for spectrum. Yet, these auctions did not incentivize competition for spectrum as they sold as many blocks as participants in the market. As a result, the revenues from these processes were very low, and spectrum assignment was likely to be inefficient.

The 2014 beauty contest illustrates these points. This process assigned spectrum in the 700 MHz (713–748 MHz and 768–803 MHz) band for the development of 4G technologies. In 2014, the Chilean mobile market had three main participants: Entel, Telefonica, and Claro. Subtel designed the 4G auction to assign three blocks. Each company could be assigned at most one block, and so companies knew they would get at least one block. After a tie in the technical project came the auction stage, where companies submitted sealed bids for each one of the three blocks. Subtel allocated the first block to the highest bidder for that block and remaining companies would compete for the rest. Clearly, companies have no incentive to be aggressive in the auction stage and not surprisingly revenues were very low. Mobile companies bid USD $20 million for the 700 MHz spectrum. As shown in Table 1, this revenue is extremely low compared to that raised in many other countries.

2.2. Spectrum caps and the supreme court decision

Spectrum caps put upper bounds on the amount of spectrum that a company can exploit to offer mobile services (Cramton, 2013; Cramton, Kwerel, Rosston, & Skrzypacz, 2011; Jehiel & Moldovanu, 2003). Different forms and variations of spectrum caps had been used in Chile. For example, in the 2014 process, each firm could get at most one block of spectrum. Spectrum caps are a common regulatory measure to promote competition and participation.

In 2018, before the 5G spectrum auction in Chile, the Supreme Court decided that Subtel should explicit a spectrum policy and get approval from the main competition authority. Subtel proposed spectrum caps that applied to spectrum holdings in different broadbands. Spectrum broadbands were divided into low (below 1 GHz), mid-low (between 1 and 3 GHz), and mid-high (between 3 and 6 GHz) bands. The idea was that because broadbands have different properties, they can complement each other. For example, the low bands have great coverage but high latency, while mid-high broadbands have high speed and low latency but low coverage.

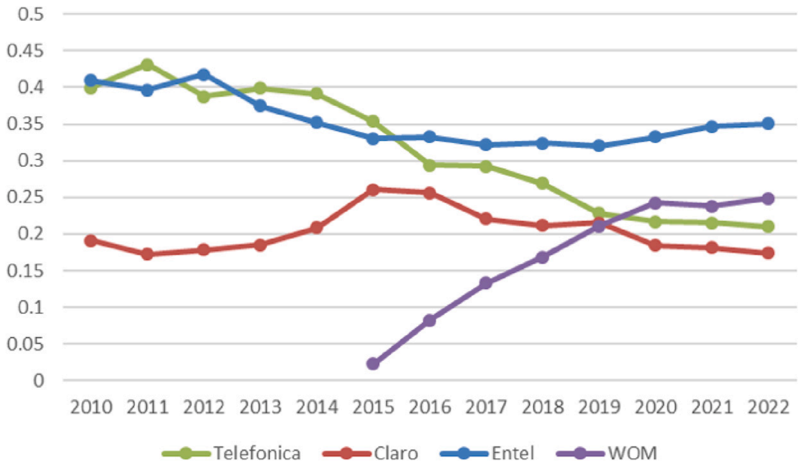

Fig. 1. Market share — Mobile internet connections.

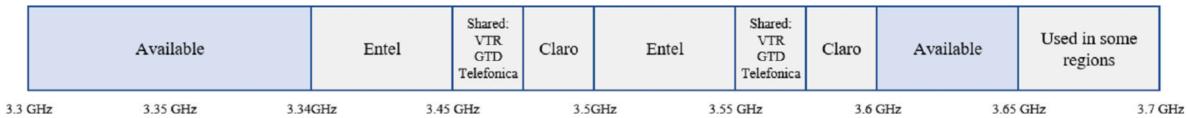

Fig. 2. Pre-auction use of 3.5 GHz band.

The Subtel proposal also emphasized that the mobile Chilean market had four serious competitors and that the spectrum policy should recognize that. As shown in Fig. 1, by 2019 the fourth operator, WOM, had become an important market participant. WOM had entered into the market in 2015 by acquiring the assets of a small network operator that possessed spectrum in the AWS band. Despite the lack of a spectrum portfolio, WOM had expanded its operations and consolidated as a key competitor, both in the wholesale and retail markets. It was then sensible to have a spectrum policy that ensured lack of spectrum was not a reason for any of the four firms to exit the market.

While some incumbents contested the very idea of having spectrum caps, the Subtel view was mostly accepted. The final decision by the Supreme Court set caps slightly more restrictive than the ones proposed by Subtel. Concretely, the spectrum caps equal 32% in low bands, and 30% for both the mid-low and mid-high bands.

In Appendix A, we give more context on the spectrum assignment before the Supreme Court decisions and 5G auction. In Appendix B, we explain some characteristics of the Chilean laws regarding spectrum; specifically, we explain spectrum usage, tradeability, and spectrum returns before the auction.

3. The 5G auction design

The whole 5G allocation process included the 700 MHz, AWS and 3.5 GHz bands. For each of these bands, a separate first price auction was conducted. In each of the lower bands (700 MHz and AWS), a single block was auctioned (20 MHz and 30 MHz, respectively). The 3.5 GHz band was divided in 15 blocks of 10 MHz each, where 10 of these blocks were in the lower part of the band (3400 MHz–3500 MHz) and the other 5 blocks were in the upper part of the band (3600 MHz–3650 MHz), as shown in Fig. 2. The 3.5 GHz spectrum was assigned by means of a combinatorial first-price auction. We now explain these design choices.

The first design decision was whether to run a single process that would allocate the spectrum in different bands simultaneously or, alternatively, assign different bands sequentially. A simultaneous process would allow firms to bid for different packages and express complementarities between different macro bands. The decision was to run the assignments sequentially in order to keep the process simple for participants. Because lower bands are necessary for coverage, the second decision was to auction the 700 MHz block first, then the AWS block and finally the 3.5 GHz blocks, allowing participants to bid in higher bands after knowing the allocation in the lower bands. This feature could also induce more competition and higher revenues as more information was available for participants.

The auction had coverage and bandwidth obligations. In the 3.5 GHz, operators committed to develop mobile networks that eventually reached 90% of the population and some industrial hubs.

One of the purposes of the 5G process was to fully consolidate four operators in the sector. That is why we decided to auction unique blocks in the 700 MHz and AWS bands. This way, a company with little or no spectrum (like WOM or an entrant) who wins these blocks would ensure a portion of spectrum viable for operation.

Another design choice was the auction mechanism. The literature shows that practical auction design involves tradeoffs that need careful evaluation (Levin & Skrzypacz, 2016; Milgrom, 2004). The particular context in which this process took place is important to understand some auction design choices. In particular, Chilean law states that the allocation of spectrum has to be conducted in a unique administrative act. According to some interpretations, this ruled out the possibility of implementing multi-round mechanisms (like Clock or Simultaneous Ascending auctions) that may take several days or even weeks (Kuś, 2020). A Vickery auction could also meet the requirements of the law, but the payment formula seemed exceedingly complex for firms and the general public. In an environment in which some incumbents were willing to challenge a competitive spectrum allocation process, a safe design choice was to assign spectrum using a first price package auction (Bernheim & Whinston, 1986; Milgrom, 2004).

Of course, the first price package auction has merits beyond its safety in the Chilean context. It allows firms to express valuations for different numbers of blocks. Under some (relatively demanding) conditions, the combinatorial first price auction is also efficient (Milgrom, 2004). The first price package auction is also easy and fast to implement, and thus the 5G technology could be launched quickly (Milgrom, 2019).

Some companies already had spectrum in the 3.5 GHz band. This spectrum had been assigned to provide fixed wireless services and was not authorized for 5G services. Entel had 100 MHz, Claro had 50 MHz, and Movistar had 50 MHz in the 3.5 GHz band. The allocation in 3.5 GHz before the auction is illustrated in Fig. 2.

The auction had to respect the spectrum caps imposed by the Supreme Court. Concretely, this meant that after the auction is run, no firm can have more than 105 MHz in the 3.5 GHz band. The Supreme Court decision allowed firms to temporarily exceed the cap and, within 6 months, return the excess. Temporarily exceeding the cap to return spectrum could be part of a rational strategy because the spectrum assigned before the auction was not authorized for providing 5G services. This was indeed the strategy followed by Entel.

The spectrum in 3.5 GHz was divided in 15 blocks of 10 MHz each, ten blocks were in the lower part of the band (3400 MHz–3500 MHz) and the other five blocks were in the upper part of the band (3600 MHz–3650 MHz). Companies bid for generic blocks in each section of the band. After the auction, the companies could choose a specific location within the band they won in descendent order of payments.

Specifically, a bid consists of a triple (p, a, b) where p is the price that the bidder is willing to pay for a combination of a blocks in the lower part and b blocks in the upper part of the 3.5 GHz band. Each bidder can present as many offers as feasible (a, b) pairs there are (i.e. up to 65 bids). After each participant makes its offers, the allocation that maximizes revenue is selected. Formally, consider $\mathcal{I}$ the set of bidders, and (p_{ij}, a_{ij}, b_{ij}) the bid j of bidder i and z_{ij} a decision variable representing whether the bid j of bidder i is taken or not. Then the problem to determine the allocation is the following IP:

$$\begin{aligned} \text{maximize} \quad & \sum_{i,j} p_{ij} z_{ij} \\ \text{subject to} \quad & \sum_{i,j} a_{ij} z_{ij} \leq 10 \\ & \sum_{i,j} b_{ij} z_{ij} \leq 5 \\ & \sum_{j} z_{ij} \leq 1 \quad \forall i \in \mathcal{I} \\ & z_{ij} \in \{0, 1\} \end{aligned}$$

The model contains two 0–1 knapsack constraints and one packing constraint for each participant. The knapsack, as well as the packing problems, are known to be NP-Hard. However, given the small right-hand side of the knapsacks and the limited number of packing constraints, we obtain a very easy formulation to solve.

4. Discussion

In this section we discuss the companies' strategies and the results of the auction.

4.1. Outcomes

In the 700 MHz auction, there were two participants, WOM and Borealnet, a potential new entrant. Neither of the participants had spectrum in the low bands. WOM paid around USD $82 million for the block of 20 MHz of spectrum in this band.

The acquisition of spectrum in the lower band allows WOM to consolidate its service and reduce its dependence on renting infrastructure from other companies. Given this allocation, it was expected that WOM would participate with more interest in the subsequent auctions in the AWS band and the 3.5 GHz band, increasing the competition in the auctions.

Three companies participated in the AWS auction. WOM, who already had 60 MHz of spectrum in the band, Claro, who had 70 MHz of spectrum in adjacent mid-low bands, and Borealnet. WOM paid around USD $22.3 million for the block of 30 MHz.

The acquisition of the AWS block by WOM left it with more spectrum in this macro band than Claro and Telefonica, which have 70 MHz each and further suggested that WOM had the intention to bid in the 3.5 GHz band. These two auctions consolidated four firms with spectrum in the low and mid-low bands.

Five companies participated in the 3.5 GHz auction. Three of these companies had spectrum in the band before the auction (but it was unclear whether that spectrum could be used to provide 5G services). Offers in the 3.5 GHz auction were as follows. Entel made two relatively aggressive offers, bidding only for 4 and 5 blocks in the lower part of the band (3300 to 3400 MHz). Telefonica and Claro made 13 offers each, corresponding to all possible combinations asking between 2 and 10 adjacent blocks (that do not

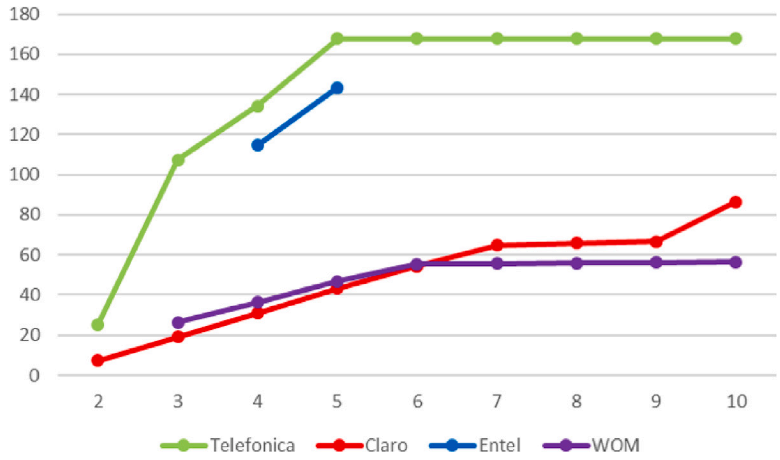

Fig. 3. Maximum offers (in Million USD) by operator by number of blocks. If we consider minimum offers instead, the graphic would be roughly the same.

mix blocks in the lower and upper part of the spectrum). These preferences indicate that obtaining less than 20 MHz of spectrum is not worth it (recall that there are coverage obligations for the winners) and that it is not desirable for the companies to acquire non-adjacent spectrum inside the 3.5 GHz band. WOM made 45 offers and bid for every possible combination between 3 and 10 blocks. The strategy followed by WOM suggests that even when WOM may prefer to have adjacent spectrum, its valuation of the spectrum is almost a function of the number of blocks alone. Borealnet made only one offer for 10 blocks, but the price per block they offered was around 10% of that of the other companies.

The auction outcomes reveal virtually no differences between revealed valuations in the upper and lower portions of the 3.5 GHz band. Of course, revealed valuations need not coincide with actual valuations. Given that the bids are virtually a function of the number of blocks, in Fig. 3 we show the bids of the firms as a function of the number of blocks being asked for (we use the maximum offers in the plot, but the same conclusions holds if we take other bids for the same amount of spectrum).

Fig. 3 shows important heterogeneity in firms' revealed valuations. Telefonica bids aggressively for up to 5 blocks, while Entel bids aggressively for 4 or 5 blocks only. As a result, the auction awarded 5 blocks to Entel and 5 blocks to Telefonica. Claro and WOM used similar bidding strategies. Yet, WOM bid slightly more aggressively for up to 6 blocks than Claro and therefore WOM obtained 5 blocks.

The auction process ended with 5 blocks assigned to Entel, Telefonica and WOM, and Claro (and Borealnet) with no blocks assigned in the band. The payments were as follows: Entel paid USD $143.39 million for 5 blocks in the lower portion of the band, Telefonica paid USD $167.83 million for 5 blocks in the lower portion of the band and WOM paid USD $46.75 million for 5 blocks in the upper portion of the band. Claro offered USD $43.26 million for 5 blocks. The total revenue of the 3.5 GHz auction was USD $357.97 million and the overall revenue of the process, considering all three auctions, was around USD $450 million.

In May 2021, it was announced that Entel would sell 30MHz of spectrum in the 3.5 GHz band to Claro. The price was around USD $12 million, significantly lower than the amounts paid at the auction. This can be due to the fact that the concession is valid until 2031 and that at the time of the exchange, the band was not allowed for use to provide 5G services, making the purchase risky.

After the purchase, Claro had to make a formal requirement to the regulator in order to change the spectrum usage and be allowed to provide mobile services. Two years after the spectrum purchase it is still unclear if this will be allowed, and if so, at what cost. Meanwhile, Entel, Telefonica and WOM are providing 5G services, the earliest since December 2021 as illustrated in Fig. 4.

4.2. Regret and efficiency

The heterogeneity in revealed valuations suggests some firms may experience some regret. We define regret as the difference between the maximum revenue a bidder could get by knowing beforehand the bids from other players and the revenue the bidder actually achieved.

Since the real valuations are not revealed in our first price auction, we cannot compute the exact regret. However, we can obtain lower bounds for the regret of the winners by computing how much less they could have paid for the same spectrum they got (assuming the rest of the bids remain the same).

Entel's regret is at least USD $96.64 million, which represents a 67% of what they paid. Similarly, Telefonica's regret is at least USD $121.08 million, which corresponds to a 72% of their payment. For WOM, in order to get the same 5 blocks there is considerably less regret given that the offer from Claro (the only lower offer) is only USD $3.5 million lower than its own offer.

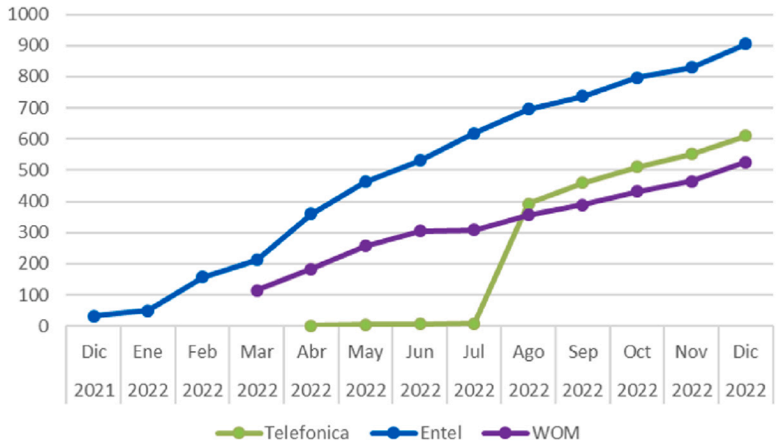

Fig. 4. Thousands of mobile 5G connections by company.

The fact that regrets are positive is to be expected given the first price aspect of the chosen design. The observation here is that in this case, regret is significant. If firms coordinated to minimize expected payments, regret should be relatively low. The significant regrets observed in the auction suggest that firms did not collude to minimize their payments.

It is also possible that Claro experienced what is called looser regret, as it could have slightly increased its bids in order to win spectrum. By raising its bid for 5 blocks by USD $3.5 million (a 8% increase), Claro would have won 50 MHz.

With respect to efficiency, an auction is considered efficient if the allocation maximizes social welfare. When we consider the utilities of both the seller and the buyers, the social welfare corresponds to the sum of the valuations of the buyers for their allocated goods. This is because whatever they pay is utility for the seller, so payments cancel out. Since the real valuations are not revealed, it is not possible to determine whether the auction was efficient or not.

We provide some evidence of this. First, it is hard to rule out the possibility that Claro's actual valuation for the 5 blocks of spectrum is above WOM's actual valuations, specially since their bids are very similar. If Claro's valuation was higher than WOM's, then the outcome would be inefficient. Now, if similar bids means similar valuations[1] then the allocation was efficient or close to efficient.

One could think about the social welfare beyond the actors in the auction. Actually it is good to remember that outside the government collecting the payments and the companies getting the spectrum, we have probably the most important actor which is the people who will use and pay for the services provided by these companies with the spectrum. If we reflect on that, it may be concerning that one of the companies did not acquire any spectrum in this band, which could lead to a more concentrated market with higher prices. However, we must notice that in order to give some spectrum to all four companies, necessarily we would have two of them with less than 50 MHz.[2]

4.3. Revenue model

Since we do not know the real valuations, it is hard to simulate the outcome under alternative auction designs. However, we argue that unless the actual valuations of Claro and WOM were more than twice their bids, the revenue would have been lower with a clock auction under some mild assumptions. We compare our results to a clock auction because they have been widely used in spectrum assignment processes (Cramton, 2013).

The clock auction expands through multiple rounds and is used to auction one or more goods. In each round, the auctioneer sets a price for each good and the participants decide how many units of each good they want. Participants can only maintain or decrease the number of units they want in each subsequent round. As long as there is more demand than supply, the auction continues and prices increase for those over-demanded goods.

The idea of the clock auction is to find a final price per unit (block) that clears the market, in other words a price such that the total demand is equal to the offer (15 blocks in this case). In practice, there is an initial price p_1 and small increments Δ_t such that the price per unit in round t is $p_t = p_{t-1} + \Delta_{t-1}$. To avoid the case in which, after an increment, there are unsold units left, bidders are usually allowed to make final offers buying units for a price in $[p_{t-1}, p_t]$. For our comparison, we make the following 3 assumptions:

[1] This is not necessarily the case, the valuations greatly influence the bids, but there may be other factors like budget or the company's beliefs about the bids of others.

[2] According to the technical team from Subtel, 50 MHz could be the minimum amount necessary to provide a good service, and if we look at the bids, for 5 or less blocks, we see supermodular functions for each firm.

Table 2
Maximum price offered per block.

Company	M USD
Telefonica	35.80
Entel	28.68
WOM	9.35
Claro	9.24

1. We assume that Entel and Telefonica would not have asked for more than 5 blocks in the clock auction. The reason why we make this assumption can be found in their bids for the auction. Entel did not bid any amount for more than five blocks, indicating that they did not wish to acquire more than 5 blocks. Telefonica did bid for more than 5 blocks, but they did not offer more money to obtain more blocks after their fifth one. In other words, they did not wish more than 5 blocks unless the extra ones were for free. This suggests that they would not ask for more than 5 blocks in the clock auction since they pay for each one they get. These behaviors can be explained by the caps in the legislation.
2. We consider a clock auction in which the 15 blocks are treated as identical,[3] therefore at each round, they all have the same price, and the firms' bid is just the number of blocks they decide to ask at that price. Even if we consider a combinatorial clock auction in which there is some distinction between blocks, we think the revenue would not change much. Looking at the bids, only Entel had a strong preference for the blocks in the lower portion (they do not bid for blocks in the upper portion). The other firms bid almost exclusively considering the number of blocks, making very small differences depending on the location of the blocks. This suggests that the other firms would probably compete only for quantity regardless of the position in the band.
3. We assume $\Delta_t \leq 1$ million dollars.

If p_T is the price in the final round, then each block is sold at a price in $[p_{T-1}, p_T]$, so the revenue is upper bounded by $15p_T$. Now we bound p_T.

Let $v_i(d)$ be the valuation[4] of player i for d blocks and $b_i(d)$ be the highest bid for d blocks in the real auction that took place. Consider a constant $c \geq 1$ such that $v_i(d) \in [b_i(d), cb_i(d)]$ for all d. Given this parameter c we can find a price for each firm at which the firm retires from the auction. If $p_t \cdot d \geq v_i(d)$ for any number of blocks d, then firm i retires from the auction, since acquiring spectrum at that price would mean negative payoff for any positive demand.[5] Therefore, firm i retires when the price per unit gets higher than $\max\{\frac{v_i(d)}{d} \;:\; d \in \{1,\dots,10\}\}$. In particular, if $p \geq \max\{\frac{cb_i(d)}{d} \;:\; d \in \{1,\dots,10\}\}$ then firm i retires.

Using this and the information from the bids (see Table 2) we conclude that Claro leaves the auction if $p_T \geq 9.24c$ million dollars. At that price we can also check that the only rational bid for WOM (whose bids were very close from Claro's bids) would be to ask for 5 blocks (any other positive demand would give them negative payoff at this point). Since the joint demands from Entel and Telefonica are at most 10 blocks given the assumptions, the auction should end when $p_T \geq 9.24c$ millions. Given that the auction did not stop earlier, we can assume $p_{T-1} \leq 9.24c$ millions. Using the last assumption about the increments, we obtain that the revenue for the clock auction is upper bounded by $138.6c + 15$ millions.

In particular, we would need $c \geq 2.47$ to obtain a greater revenue with the clock auction (since the actual collection was USD $357.97 million). In other words, unless Claro's bids were below 40% of their real valuation, a first price package auction generates more revenue.

Note that even if Claro's bids were below 40% of their real valuation, we could get similar bounds if WOM's bids are above 40% of their valuations since their bids are very close to each other.

The revenue model suggests that the Chilean 5G auction collected significant revenues given the estimated valuations of participants. While inefficiencies cannot be ruled out, we are confident that the process was more competitive, efficient, and transparent than previous spectrum allocations.

5. Conclusions

The 5G spectrum auction in Chile constitutes an important change in the way in which a scarce and valuable resource – spectrum broadband – was being allocated. We designed and implemented a first-price package auction for two sections of the 3.5 GHz spectrum band. The new format is a transparent way to allocate spectrum and resulted in significant revenues for the Chilean government. The overall process resulted in more then USD $450 million in revenues, 6 times more than the revenue from all previous contests in the country.

The transition from a beauty contest to an auction procedure required careful consideration of the recent market evolution, as well as the political and legal context in which the allocation took place. The assignment process took place in the middle of a

[3] This assumption is mostly used to simplify the argument and the notation, but the main idea remains even when blocks are not identical.

[4] It is important to consider that we normalize the valuation of being out of the auction to zero, and thus the valuations of spectrum are in reference to this baseline.

[5] More formally, any strategy in which you bid risking to pay a price higher than your valuation is dominated by a strategy in which you just leave the auction.

Table 3
Spectrum allocation by company and macro-band before the 5G auction.

MHz	Claro	Entel	Telefonica	WOM
Low (≤ 1 GHz)	45	50	45	
Mid-low (1 – 3 GHz)	70	100	70	60
Mid-high (3 – 6 GHz)	50	100		

Includes country level licenses and companies that participated in the 5G process only.

major political crisis in which citizens distrusted political actors and institutions. While some incumbents challenged the transition to an auction, the new process and its outcomes have been widely praised by the media, policymakers and politicians. The auction process has not been questioned by the Chilean society, in contrast to many other public concessions — like water and highways.

While the legal framework under which the 5G auction took place was the one used in previous allocation processes (beauty contests), the outcome was radically different. The 5G imposed obligations to winning firms and, at the same time, was designed to promote competition for blocks among participants. We expect the future allocation processes in Chile to keep the emphasis on the price system to allocate electromagnetic spectrum.

There is room for improving spectrum management in Chile. Alternative auction designs and multi-round procedures (as the ones used in the US and the UK) should be evaluated in future assignment processes. Spectrum in Chile is currently assigned for 30 years. This seems excessive in a dynamic industry such as telecommunications and is well above the length of licenses used in developed countries. As argued by Milgrom, Weyl, and Zhang (2017), while long licenses may incentivize some investments, shorter licenses promote efficiency and competition. These and other public policy issues relating to spectrum management need urgent discussion in Chile.

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Appendix A. Spectrum allocation before the auction

For the Chilean spectrum policies, the low band includes spectrum under 1 GHz, the mid-low band includes spectrum between 1 GHz and 3 GHz and the mid-high band includes spectrum between 3 GHz and 6 GHz.

In Table 3 we provide a summary of the allocation of spectrum by company and macro-band in 2018, before the 5G auction took place, and before the companies had to return spectrum (see Appendix B).

Appendix B. Regulatory information

Spectrum use:

With respect to the use of the band, spectrum can only be used to provide the services it was acquired for. For example, if a company has a license of spectrum in a band that is to provide radio communications, it cannot be used to provide any other services unless the regulator allows it.

The spectrum in the 3.5 GHz band that was assigned before the auction was assigned to explore fixed wireless services and not for providing 5G services. The only way, at the time of the auction, to provide 5G services was acquiring new spectrum in the band in the 5G auction.

Tradeability of spectrum:

Spectrum trade in the secondary market is also regulated. Companies can only sell a complete license of spectrum to another company, not a portion of a license. It is the regulator who has to allow the transaction details.

Spectrum returns before 5G:

In 2018, at the same time that the Supreme Court decided that a spectrum cap policy was needed, it ruled that companies that acquired spectrum in the previous beauty contest for the 700 MHz band had to return spectrum. More specifically, the decision was that companies needed to return spectrum in any spectrum band they chose.

Because of this, Entel was allowed to modify its 3.5 GHz concession and return 20 MHz in that band and 10 MHz in 900 MHz band. Claro on the other hand also decided to modify its concession and return 20 MHz in the 3.5 GHz band. Telefonica chose to return 10 MHz in the 1.9 GHz band and 10 MHz in regional concessions in the 3.5 GHz band.

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