

Identifying the Winner's Curse in the First Spectrum Auction in the Republic of Korea Using an Event Study Approach

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The first spectrum auction in the Republic of Korea is attention-worthy owing to the fierce competition for the only 1.8-GHz spectrum license, the winning bidder of which was suspected of overpaying for its acquisition. This study empirically investigates the existence of a “winner’s curse” in the first Korean spectrum auction by using a standard event study methodology. The results show that both the winner and loser experienced significant positive returns on the completion day of the auction. The results imply that there was no winner’s curse in the auction and that the losing firm might increase its competitive advantage by acquiring other spectrum licenses despite failing to achieve its initial target spectrum. Therefore, these results suggest that regulators may need to consider bringing about positive short-term wealth benefits to all bidders by appropriately designing a spectrum auction, such as by performing multiband auctions.

Keywords: Spectrum auction, overbidding, winner’s curse, event study, 4G spectrum.

I. Introduction

As the demand for and value of spectrum resources significantly increases [1], it is essential to use the limited spectrum resources as efficiently as possible [2]. With various attempts to achieve efficient spectrum management, including spectrum sharing [1] and spectrum usage rights [3], the use of auctions has become increasingly widespread [4] and is currently the most popular mechanism for assigning spectrum in the telecommunications markets [5]. The auction approach has been regarded as a faster, more transparent, and less costly way of spectrum assignment than “beauty contest” processes [6]. The Korean regulator, the Korean Communications Commission (KCC), auctioned off three national spectrum licenses, including the 2×5 MHz bandwidth of the 800-MHz spectrum band, the 2×10 MHz bandwidth of the 1.8-GHz spectrum band, and the 2×10 MHz bandwidth of the 2.1-GHz spectrum band, starting in August 2011, and expects to assign other spectrum resources using this approach according to its national spectrum strategy, called the “Mobile Gwanggaeto Plan”¹⁾ [7].

One interesting result of this auction was that two of the three Korean mobile operators focused on bidding for a single 1.8-GHz spectrum license, with the winning bid at US\$926 million, more than twice the reserve price. The results caused a dispute questioning whether the final bid was inflated and would result in higher costs to Korean consumers. However, this was not the first time concerns have been raised over a so-

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1) According to the plan, the KCC will secure the spectrum over the 600-MHz bandwidth, phase by phase, until 2020 for mobile communication services.

called “winner’s curse,” a phenomenon whereby the winning bid is greater than the true value of the asset [4], [8] in spectrum auctions. Previous studies have investigated whether winning companies experienced such a curse in the European 3G spectrum auctions [4], [8], [9]. If a winner’s curse occurred during the Republic of Korea’s first spectrum auction, it would indicate that the government needs to rectify its forthcoming auction design. Therefore, it is necessary to examine whether the winning bidder overpaid during the Republic of Korea’s first spectrum auction.

Therefore, using an event study methodology, this paper seeks to determine whether the winners of the Republic of Korea’s first spectrum auction overpaid for the spectrum they acquired. This study may be the first attempt to examine the auction results for a winner’s curse in a Korean auction. Although previous literature has examined the existence of a winner’s curse in European 3G auctions using an event study approach [4], [8] and real option technique [9], the results might not be sufficient for the identification of a winner’s curse in the first Korean auction, since they were limited to 3G auctions in countries such as the United Kingdom (UK) and Germany. Because the Korean case corresponds to the spectrum auction for advanced mobile communications services (4G) including Long Term Evolution (LTE), our results may provide a better understanding of the value of the 1.8-GHz spectrum in the Republic of Korea with policy implications.

The remainder of this article is organized as follows. In section II, we review the related literature on the existence of a winner’s curse in spectrum auctions and suggest a research hypothesis, focusing on the results of the 1.8-GHz spectrum license in the first Korean spectrum auction. Section III describes the data and method used. Section IV presents empirical results and a discussion on their implications. Some concluding remarks are then given in the final section.

II. Related Literature and Research Question

1. Related Literature

Since New Zealand began using a second-price, sealed-bid auction, an increasing number of countries have been relying on auctions for spectrum management [10]. On one hand, auctions are widely regarded as more efficient [11], transparent [12], and revenue-maximizing [13] methods over so-called “beauty contests” for assigning spectrum resources. Others have criticized the mechanism, arguing that spectrum auctions can increase the license fees and the final consumer prices, and bidders can thus bid more than the real value of the spectrum under highly competitive circumstances, resulting in high

financial costs and investment delays [14].

Despite previous studies not finding empirical evidence to support these negative effects of spectrum auctions in the mobile communications market [14], [15], doubts concerning the overbidding of mobile operators still remain after some European 3G auctions ended with unexpectedly high prices. In particular, a major concern over spectrum auctions is that the up-front license fees might lead to a winner’s curse [16], a phenomenon whereby the winning bid is greater than the true value of the spectrum asset [4], [8]. Whether a spectrum auction can suffer from a winner’s curse is impossible to say with theory alone; the identification of a winner’s curse should be an empirical matter [4]. However, only a few previous studies have attempted to empirically investigate whether the winning companies experienced a winner’s curse in some specific 3G auctions, such as those in the UK and Germany, in which unexpectedly high license fees were observed. First, the possibility of a winner’s curse in the UK’s 3G spectrum auction in 2000 was examined using an event study method [8] and option pricing technique [9], but there was no systematic evidence of a winner’s curse in the auction. Second, using the same event study approach, in Germany’s 3G spectrum auction in 2000, Mackley [4] empirically found that there was at least short-term evidence of a winner’s curse.

An interesting point in the literature is that there is no consistency about whether a winner’s curse existed in the spectrum auctions. There have been strong suggestions that the winning companies overpaid in both auctions [8], but they found different results regarding the existence of a winner’s curse. This implies that the existence of a winner’s curse in a specific region or country can be affected by the specific regional or national context. The first Korean auction to assign 4G spectrum licenses was different from those for the 3G bandwidth. Thus, the results of previous European 3G spectrum auctions might not be sufficient for the identification of a winner’s curse in the first Korean auction, and it is therefore necessary to empirically examine whether the winning Korean mobile carrier overpaid during the auction.

2. Research Question

The Korean government has previously relied on “beauty contests” to assign spectrum licenses, but it decided to introduce an auction system for greater efficiency under the amendment of the Radio Waves Act of June 2010. Because an auction can allow a spectrum to be assigned to operators who are able to extract maximum benefit for themselves and for society [15], it has been increasingly popular in many countries [1]. The Korean regulator then decided to assign the spectrum using this approach for the first time to cope with the rapid

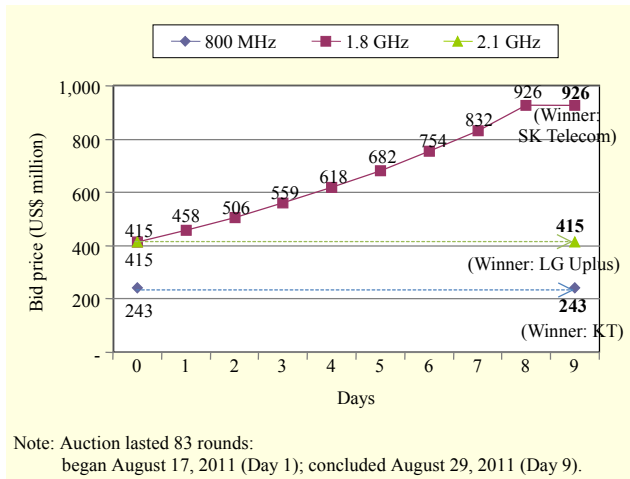


Fig. 1. Spectrum auction results in Rep. of Korea.

growth of mobile broadband markets in correlation with a high degree of smartphone adoption. In August 2011, the regulator performed simultaneous multi-round ascending bid auctions for three national spectrum licenses: 2×5 MHz bandwidth of the 800-MHz²⁾ spectrum band, 2×10 MHz bandwidth of the 1.8-GHz spectrum band, and 2×10 MHz bandwidth of the 2.1-GHz spectrum band.

The auction progressed from August 17 to August 29 in 2011 (nine working days), as described in Fig. 1. The first Korean auction is quite attention-worthy since there was fierce competition between only SK Telecom, the largest mobile operator, and KT, the second-ranked mobile carrier, for the 1.8-GHz spectrum license (2×10 MHz bandwidth). The 2.1-GHz spectrum license (2×10 MHz bandwidth) was acquired by the third biggest mobile operator, LG Uplus, at the reserve price without any competition since the other companies were not allowed to bid for it to avoid a spectrum monopolization of the spectrum band [7]. LG Uplus then decided not to bid for the other spectrum license. While the 800-MHz spectrum has been the most attractive spectrum band in European countries for advanced mobile broadband services, such as LTE,³⁾ the spectrum license did not attract much attention from potential bidders in the Republic of Korea since it may provide insufficient capacity (2×5 MHz bandwidth) for advanced services.⁴⁾ Because at least a 2×10 MHz bandwidth as a single

2) Technically, the spectrum license was included in an “extended 850-MHz” band spanning 814 MHz to 849 MHz and 859 MHz to 894 MHz, differing from the European 800-MHz digital dividend band spanning 791 MHz to 821 MHz and 832 MHz to 862 MHz.

3) According to previous studies, lower frequencies have more value for mobile operators, owing to better propagation and penetration characteristics [15], [17]. For example, in the German spectrum auction in May 2010, the 800-MHz spectrum license was the most valued, almost ten times that of the 2-GHz license [15].

4) In general, LTE allows for an overall system bandwidth ranging from as small as 1.4 MHz up to 20 MHz, where the latter is required to provide the highest LTE data rates [18], and a bandwidth of at least 20 MHz has been commonly used to offer commercial LTE service.

spectrum license was required for commercial advanced mobile broadband services including LTE, the Republic of Korea’s mobile operators, except LG Uplus, focused on bidding for the 1.8-GHz spectrum rather than the 800-MHz spectrum. KT eagerly wanted to acquire the license because the firm already established an LTE network in the 1.8-GHz spectrum band. Although SK Telecom’s initial main LTE network was based on the 800-MHz spectrum band, the firm also made a full effort to acquire the 1.8-GHz spectrum license to make a spectrum portfolio for LTE and LTE-Advanced services. Finally, after 83 rounds, KT pulled out of the 1.8-GHz spectrum bidding and SK Telecom acquired the desired license. KT gained the 800-MHz spectrum license at the reserve price instead.

Because the winning bid for the 1.8-GHz spectrum was about US\$926 million, more than twice the reserve price of US\$415 million, there have been strong suggestions that the winning company may have greatly overpaid. The two competing bidders also commented that the winning bid might be overpriced.⁵⁾ The recent research report by DotEcon also provided a meaningful clue to the possibility of a winner’s curse in the Korean spectrum auction, suggesting that the average value of the 1.8-GHz spectrum ranges from £0.146 to £0.219 per MHz per capita,⁶⁾ clearly less than that of the Korean auction⁷⁾ [19]. As mentioned previously [4], the occurrence of a winner’s curse in spectrum auctions needs to be identified at an earlier point since such an occurrence can indicate the need for rectifying the auction mechanism. Therefore, it is necessary to empirically investigate whether the winner, SK Telecom, overpaid for the 1.8-GHz spectrum license in the auction, since this has not been addressed yet.

The research question in this study is consequently as follows: Did the winning bidder overpay for the 1.8-GHz spectrum license in the Korean auction, indicating the existence of a winner’s curse? In particular, as a definition of a winner’s curse in the auction, we consider not only a case in which the winning bid is greater than the true value of the asset, called the strong form of a winner’s curse, but also a case in which the value of the asset is less than the expected value so that the winning bidder has disappointing profits, called the weak form of a winner’s curse. In other words, even though the winning bid is less than the true value of the 1.8-GHz spectrum license, if the value does not exceed the winning bidder’s expected value such that its subsequent returns are disappointing, this

5) See the article entitled “1800 MHz the Star of Korean Tri-band Auction” (August, 2011) (retrieved May 29, 2012, from <<https://www.policytracker.com/headlines/1800-mhz-the-star-of-korean-tri-band-auction/?searchterm=Korean.>>).

6) According to Nachira et al. [15], the value per MHz per capita can be used as a reference presenting the economic value of the spectrum.

7) From the auction, the 1.8-GHz spectrum value in the Rep. of Korea was US\$0.962 per MHz per capita, which is equivalent to £0.594 per MHz per capita.

paper judges the winning company to have overpaid for the spectrum license in the Korean auction.

III. Event Study Method

To investigate whether there was a winner's curse in the first Korean spectrum auction, we use the standard event study methodology. There have been numerous studies using the power of the event study methodology in management research [20], including two previous studies mentioned in the previous section [4], [8]. In general, this approach provides researchers with a powerful tool to assess the links between managerial decisions and actions and the resulting value created for a firm [20] by measuring the impact of a specific event on the firm's market value [21]. Therefore, it has been widely used to not only see if takeovers had a positive/negative effect on shareholder wealth [22]-[25] but also to evaluate the economic effects of classes of phenomena that would otherwise be hard to measure [26]. As mentioned in [8], no one knows whether the companies paid too much; thus, the event study approach is not a perfect method to judge if there is a winner's curse in spectrum auctions. However, the approach is one way to examine the existence of a winner's curse in spectrum auctions because it enables comparison of the amounts paid for the licenses with the market estimate of what they were worth [8]. In particular, if stock markets punish the winning bidders for paying too much in the spectrum auctions [8], the event study method may provide a better answer to this question, since it considers both the strong and weak form of a winner's curse.

According to this method, under the assumption of investor rationality and semi-strong market efficiency, the impact of an unanticipated event is expected to be fully and instantaneously incorporated into a firm's market value. Controlling for other contemporaneous events, the change in market value of the firm from its expected value should provide an estimate of the new information value, measured in terms of abnormal returns. In this study, any abnormal return will reflect a differential in the true valuation of the licenses and the fee paid by the firm [4]; positive abnormal returns indicate that the winning bidder obtained a bargain, whereas negative abnormal returns show the existence of a winner's curse and the need to rectify the current auction mechanism.

To examine the stock market reaction to auction related announcements, we use the market model, which is the most commonly used model in event studies [23]. The market model is a statistical method that relates the return of any given security to the return of the market index. Relying on the Korea Composite Stock Price Index (KOSPI), we use the model as a market benchmark in the model specified in (1).

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \quad (1)$$

where R_{it} is the realized return of the share of the bidder at time t , R_{mt} is the realized return on KOSPI at time t , ε_{it} is the error term, α_i is the intercept, and β_i is the parameter of the regression equation.

Abnormal returns (ARs) are then calculated from the difference between the actual and predicted returns using the market model approach, as described in (2).

$$AR_{it} = R_{it} - (\alpha_i + \beta_i R_{mt}) = \varepsilon_{it} \quad (2)$$

The returns during the event period are accumulated to calculate the cumulative abnormal returns (CARs) for the stock, as shown in (3). CARs are also a good indicator because they capture the total firm-specific stock movement for an entire period when the market might be responding to new information [27], [28].

$$CAR(t_0, t_1) = \sum_{t=t_0}^{t_1} AR_{it} \quad (3)$$

An appropriate test can be used to determine whether such measured wealth effects differ significantly from zero [28]. For this purpose, a t-statistic was used to assess the statistical significance of CAR and was constructed as described in (4).

$$T = CAR(t_0, t_1) / SD(t_0, t_1) \quad (4)$$

$SD(t_0, t_1)$ is an estimate of the standard deviation adjusted for the auto covariance of returns, which was used by previous studies [27], as described in (5).

$$SD(t_0, t_1) = \sqrt{(t_1 - t_0 + 1) \text{Var}(AR_t) + 2(t_1 - t_0) \text{Cov}(AR_t, AR_{t-1})} \quad (5)$$

In this study, to estimate the parameters in the market model, the estimation window from 190 trading days to 11 days prior to the first date of the spectrum auction is used. We then examine two event windows according to the subsequent events related to the auction. First, on August 17, 2011, the first spectrum auction was started in the Republic of Korea. While LG Uplus won the 2.1-GHz spectrum in an uncontested auction, the other two mobile carriers, who had not been allowed to bid for the 2.1-GHz spectrum, began to fight for the remaining spectrum licenses, particularly the 1.8-GHz spectrum license. Second, on August 29, 2011, the auction ended after KT pulled out of the bidding for the 1.8-GHz spectrum license. SK Telecom won the desired spectrum, paying about 925 million dollars, whereas KT gained the 800-MHz spectrum instead. The timeline shown in Fig. 2 reflects the estimation period and all relevant event dates.

To examine the consequences of shareholder wealth on the spectrum auction, we utilize the KISVALUE database, one of

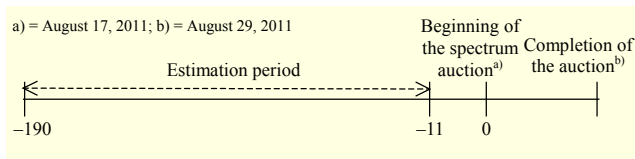


Fig. 2. Estimation period and event dates.

the most reliable databases in the Republic of Korea, for the stock price and financial information.

IV. Empirical Findings

1. Results

We focus on the short-term shareholder wealth effects associated with the two auction-related announcements; the results of the event study for the bidders are presented in Table 1 and Fig. 3⁸⁾. First, both bidders experienced positive shareholder wealth creation around the beginning of the spectrum auction (August 17, 2011). At the start of the auction, they had a significantly positive AR on the preceding day, the day of, and the following day, that is, AR(-1), AR(0), and AR(1), respectively. Over the three days, both firms cumulatively earned positive returns of more than 12.0%. This rise may indicate that the first spectrum auction in the Republic of Korea could be interpreted as “good news” to the marketplace because both bidders expected an increase in their competitive advantage by acquiring the attractive 1.8-GHz spectrum license.

Second, both firms experienced significant shareholder wealth loss before the completion of the auction. Over the three preceding days, they earned statistically significant negative returns of more than -7.0%. These results may imply that the competition between them became fierce while the auction was under way and that uncertainty thus existed concerning the spectrum acquisition. In fact, during the auction, there were some concerns published in the domestic media about potentially fierce competition between bidders and the possibility of a winner’s curse.⁹⁾

Third, on the date the auction closed (August 29, 2011), the winning bidder, SK Telecom, experienced positive shareholder wealth creation once again; the firm earned statistically significant positive returns of about 2.8%. This may indicate that there was no winner’s curse in the auction. The loser, KT,

also had a significantly positive return of about 3.2% on the auction completion day. One possible explanation is that the other spectrum (800-MHz band) acquired by the firm could also contribute to its competitive advantage regardless of its loss in the auction, even though the result was not the

Table 1. Event study results for bidders in spectrum auction in the Rep. of Korea.

| | Event day and window | Winner (SK Telecom) | Loser (KT) |
|----------------------------------------|----------------------|---------------------|------------|
| Panel A: beginning of spectrum auction | AR(-3) | 2.90%*** | -2.50%** |
| | AR(-2) | -0.17% | 0.37% |
| | AR(-1) | 2.38%** | 2.49%** |
| | AR(0) | 4.84%*** | 3.02%*** |
| | AR(1) | 7.19%*** | 6.62%*** |
| | AR(2) | -0.49% | 0.31% |
| | AR(3) | 1.47% | -0.01% |
| | CAR(-3, 0) | 9.96%*** | 3.38% |
| | CAR(-1, 0) | 7.23%*** | 5.51%*** |
| | CAR(0, 1) | 12.04%*** | 9.64%*** |
| | CAR(0, 3) | 13.01%*** | 9.94%*** |
| | CAR(-1, 1) | 14.42%*** | 12.12%*** |
| | CAR(-3, 3) | 18.13%*** | 10.29%*** |
| Panel B: completion of auction | AR(-3) | -3.27%*** | -2.13%** |
| | AR(-2) | 0.53%*** | -1.66%* |
| | AR(-1) | -5.47%*** | -3.24%*** |
| | AR(0) | 2.83%** | 3.21%*** |
| | AR(1) | 1.12% | -0.92% |
| | AR(2) | 1.32% | -0.24% |
| | AR(3) | -2.19% | -1.44% |
| | CAR(-3, 0) | -5.39%** | -3.82%* |
| | CAR(-1, 0) | -2.65% | -0.03% |
| | CAR(0, 1) | 3.94%** | 2.29% |
| | CAR(0, 3) | 3.07% | 0.61% |
| | CAR(-1, 1) | -1.53% | -0.95% |
| | CAR(-3, 3) | -5.14% | -6.42%** |

Note: AR = abnormal return and CAR = cumulative abnormal return of winning and losing bidders, SK and KT, respectively; CAR(-3, 0) reflects day of auction announcement and three preceding days; CAR(-1, 0) reflects day of auction announcement and preceding day; CAR(0, 1) reflects day of auction announcement and day after; CAR(0, 3) reflects day of auction announcement and three days after; CAR(-1, 1) reflects preceding day of auction announcement and day after; CAR(-3, 3) reflects three preceding days of auction announcement and three days after; and *, **, and *** represent one-tailed statistical significance at 10%, 5%, and 1% levels, respectively.

8) While previous studies examined the performance of the portfolio of winning and losing firms for multiple licenses in the European 3G spectrum auctions [4], [9], this paper treats only a single winner and loser in the Korean spectrum auction. The results are therefore expected to identify the existence of a winner’s curse in the auction more clearly.

9) For example, see the article entitled “Wireless Spectrum Auction - A Trillion-Won Game” (August, 2011) (retrieved May 29, 2012, from <http://www.koreatimes.co.kr/www/news/biz/2011/08/335_93656.html>).

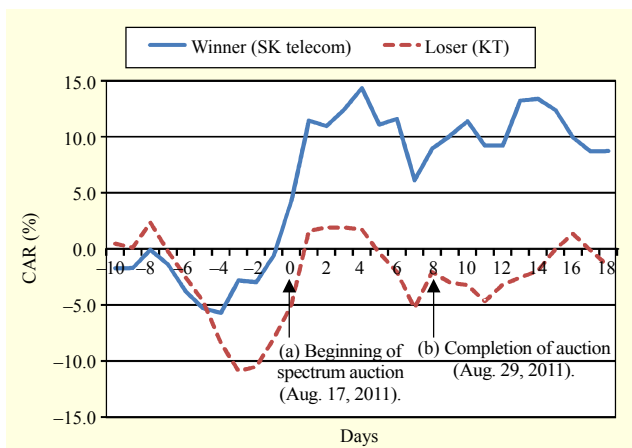


Fig. 3. CAR trend of bidders in spectrum auction in Rep. of Korea.

preference of the operator.

Figure 3 provides a graphical clue of how the spectrum auction affected the bidders' short-term market performances. As shown in the figure, while the auction was underway, the losing bidder seemed to experience insignificant shareholder wealth creation even though it gained an alternative spectrum license; the winner clearly seemed to generate positive shareholder values through the auction. Therefore, the results in this study support the idea that there was no winner's curse in the first Korean spectrum auction.

2. Discussions

Using the event study approach, we empirically confirm that despite the concern over a potential overbidding for the attractive 1.8-GHz spectrum, the mobile operator had positive shareholder wealth creation, indicating that there was no winner's curse in the first Korean auction. Considering that the prices for a spectrum reflect the economic value that the spectrum generates for the operators and society [17], the results suggest that the value of the 1.8-GHz spectrum for LTE exceeds both the winning bid and the winning bidder's expected value. If the results indicate that the price paid during the auction is close to the true value of the 1.8-GHz spectrum, it is possible to estimate the market value of the other spectrum bands using the previous literature.¹⁰ Therefore, the Korean government can consult the results when it sets reserve prices in the next spectrum auction. To establish their next spectrum auction strategies, the Korean mobile carriers can also view the winning bid as the potential value of the 1.8-GHz spectrum. In particular, in the next spectrum auction in the Republic of

¹⁰ For example, after benchmarks, DotEcon mentioned that the value of the 800-MHz spectrum is approximately two to three times that of the 1.8-GHz spectrum, and the value of the latter is roughly double that of a paired 2.6-GHz spectrum [19].

Korea, the other 1.8-GHz spectrum licenses will be assigned; thus, the three mobile operators will compete for the licenses for their advanced mobile broadband services, called LTE-Advanced. Therefore, the result from the first auction can be a reference case for setting their estimate of the value of the 1.8-GHz spectrum.

Another interesting result is that the losing bidder also experienced a significant positive return on the completion day of the auction. This may be an unexpected result since the competitor would be at a competitive disadvantage by failing to acquire the 1.8-GHz spectrum they wished to acquire. One possible explanation is that the market recognized that the firm can avoid a winner's curse by giving up the spectrum, but this might not be very persuasive since this study shows that there was no winner's curse in the auction. A more convincing argument is that the market assessed that the losing bidder can still increase its competitive advantage by acquiring the other (800 MHz) spectrum, although it failed to achieve its initial goal. Thus, this may suggest that the Korean regulator needs to consider multiband auctions, which could bring further alternatives for all bidders in future auctions. In the case of the 3G mobile license auctions in Europe, all bidders had only one chance to obtain the licenses without any alternatives [4], [8], and there thus existed significantly fierce competition between bidders, bringing into question the existence of a winner's curse in the UK and Germany. However, in the recent multiband auctions for LTE services in European countries, mobile service providers generally obtained the spectrum licenses at prices lower than the real value [15], as they were able to obtain second-best options though failing to achieve their original objectives.¹¹ In particular, the first Korean spectrum auction might suggest that policy makers may be able to alleviate fierce competition between bidders and bring about positive short-term wealth effects for all bidders by designing multiband auctions appropriately. Since the availability of multiple spectrum bands within an auction offers mobile operators the opportunity to switch between bands and develop alternative strategies depending on the development of the auction, multiband auctions could be regarded as "good news" to the market, enabling potential bidders to bring short-term wealth benefits.

The results of this study also suggest that the Korean government needs to alter some factors that may increase fierce competition between bidders. First, the government needs to secure as sufficient and contiguous a spectrum (at least the 2×10 MHz bandwidth) as possible for a single license for

¹¹ For example, see the article entitled "Big Three Operators Happy with Low-Cost German Auction" (May 2010) (retrieved May 29, 2012, from <[https://www.policytracker.com/headlines/big-three-operators-happy-with-low-cost-german-auction/?searchterm=Germany auction](https://www.policytracker.com/headlines/big-three-operators-happy-with-low-cost-german-auction/?searchterm=Germany%20auction)>).

advanced mobile broadband services, including LTE and LTE-advanced. Insufficient bandwidth (2×5 MHz) of the 800-MHz spectrum license could be one of the reasons why the value of the spectrum license was quite undervalued in the first Korean auction. Therefore, several options for a sufficient and contiguous spectrum license enable potential bidders to avoid concentrating on a single specific license. Second, the policy makers also need to remove restrictions on bidding in the specific spectrum license for future auctions. In the first auction, the Korean regulator prohibited the two big mobile operators from bidding for the 2.1-GHz spectrum to avoid spectrum monopolization of that spectrum band. Although this rule was successful in balancing the quantity of the spectrum of the three mobile carriers, it may have contributed to fierce competition between the bidders for the 1.8-GHz spectrum. Considering that the third Korean mobile operator currently has over 10 million subscribers and has become the second mobile carrier in terms of LTE subscribers in the domestic market, the Korean government could consider stopping a spectrum reservation for the mobile operator in upcoming spectrum auctions.

In summary, this study finds no evidence of a winner's curse in the first Korean spectrum auction. We also suggest that an appropriately well-designed auction mechanism may prevent a winner's curse and bring about positive short-term wealth benefits for all bidders.

V. Conclusion

The first spectrum auction in the Republic of Korea has garnered a significant amount of attention because there was fierce competition to acquire the license for the 1.8-GHz spectrum and the winning bidder was suspected of overpaying. We attempted to investigate the existence of a "winner's curse" in the auction, using an event study methodology. We confirmed that both the winner and loser experienced a significant positive return on the completion day of the auction. Our results indicate that there was no winner's curse in the Republic of Korea's first auction. The results also imply that the losing firm increased its competitive advantage by acquiring the other spectrum band, even though it failed to achieve its initial objective. Therefore, we suggest that regulators should consider bringing about positive short-term wealth benefits to all bidders by appropriately designing spectrum auctions, such as performing multiband auctions and other treatments. Mobile operators also can prepare for future spectrum auctions and plan for shareholder value creation using the auction results as a point of reference.

Although we presented some meaningful implications for spectrum management, this study also had some limitations. First, by limiting the focus of this study to a particular auction

in the Republic of Korea, the generality of the empirical results should be treated with caution. Therefore, a useful area of future research would be to extend the empirical analysis to recent spectrum auctions in other countries. Second, this study employed the event study approach to test for a winner's curse but the method may not answer whether the winning bidder suffers from winner's curse in the long term. Therefore, future research could examine the existence of the winner's curse in the Republic of Korea's first spectrum auction from the long-term perspective, if the data is sufficient for empirical analyses. Third, we focused on the existence of a winner's curse in the spectrum auction but did not sufficiently examine some factors that impacted the realized auction revenue in terms of the winning bid. Therefore, in the international context, further research could examine the impact of such factors on 4G spectrum auction results in terms of the winning bid.

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