The Third Generation (3G) Auction in Asia

By Chalita SRINUAN*

Abstract

This study examines a winner's curse in the third generation (3G) spectrum auction for selected Asian countries during 2000-2006. The winner's curse is a phenomenon that a winner will tend to overpay in an auction, making the license unprofitable. An event study has been employed as a method in order to assess a winner's curse through the analysis of security prices of the firms involved in the auction. The cumulative abnormal return of stock price post auction indicates whether the firm in question paid too much for the license. The results reveal that there is a mix of positive and negative cumulative abnormal returns of winner firms. Most of the winner firms have a negative cumulative abnormal return until the end of auctions. After fourteen days, there are signs of reward since the stock prices of winning bidders increase. This finding indicates that the 3G licenses in Asian countries face a very short term of winner's curse. The short period of a negative abnormal return is obtained by the reduction of reserve price and relaxation of the licensing condition by National Regulatory Agencies (NRAs).

Introduction

Recently, the third-generation[1] (3G) spectrum auctions in the UK and Germany have been discussed according to their high bidding prices. One reason for high bidding prices is that an overoptimistic estimate of a license's value for the firm results in overbidding (McMillan, 1995). The reason for overbidding is the interest of the Mobile Network Operators (MNOs) to become market leaders and gain long-term profit. The result of overbidding by an auction winner could be a worse situation – a so-called winner's curse. The bidding winner can be said to be cursed either if the winning bid exceeds the value of the asset, or if the value of the asset is less than the expectation. In the former case, the firm loses money; in the latter, the winning firm gains lower profits than expected. For example, the high bidding prices of 3G auctions in the UK and Germany were a major factor in explaining the loss in market value of the firms, since the licenses were a burden

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for firm growth over the long run. Also, if the auction prices were to go very high, this could lead to an increase in the cost of capital of firms, which in turn could delay innovation (McMillan, 1994).

For Asian countries, 3G could be a key technology for enhancing social welfare, if the firms design their 3G assignment to best realize the full economic value to consumers, industry and taxpayers. Most Asian countries have mobile penetration rates higher than fixed line (ITU, 2009). But only 7 countries were granted 3G licenses lately: Hong Kong, Indonesia, Korea, Malaysia, Philippines, Singapore and Taiwan. The licenses in four countries (Hong Kong, Indonesia, Singapore and Taiwan) were granted by auctions, and the rest were obtained by beauty contests.

The 3G auction in later-mover countries as in Asia may show that high bidding prices cause a decrease in market value of telecommunication firms and markets. Thus, the National Regulatory Authorities (NRAs) proposed different auction designs in order to avoid the winner's curse problem. For example, Hong Kong uses the royalty payment. The Hong Kong regulator believes this method will encourage market entry since the licensee need not pay until 3G services revenues are actually achieved, while keeping the financial burden at a manageable level (Yan, 2004). Another case is Singapore; the auction reserve price has been reduced from the S$150m announced earlier to S$100m by the Infocomm Development Authority (IDA), in response to feedback from potential bidders. The NRAs expected that this adjustment will facilitate the successful rollout of 3G services, which is strategic to Singapore's ambitions to be an Asian leader in mobile communications. The examples of the NRAs' actions show that they decrease the auction fee in order to reduce the negative reaction of firm market value (Yan, 2004).

Even so, the question of a winner's curse in 3G auctions in Asia still exists and calls into question the use of auctions to assign licenses. The existence of a winner's curse in the short run suggests that the market is imperfect. But if a winner's curse remains in the long run, it will indicate that there are inefficiencies in the assignment method used by NRAs. For example, if the reserve price that NRAs choose at the beginning is too high, this could lead to overpriced auctions. Therefore, the existence of a winner's curse can be a reason to relax the licensing condition and regulatory environment.

This investigation follows the event study method which was used in Cable et al. (2002) and Mackley (2008) in order to investigate the winner's curse in 3G auctions. The event date is defined as the announcement date of the bidding result by the NRAs. But the defined event windows in this study are 1, 7, 14 and 30 days after the event date, which differs from the studies of Cable et al. (2002) and Mackley (2008) since these two papers used only 1 day and 30 days after the auction was made. The reason is to investigate overall interferences along the event

period.

Following this introduction, Section 2 briefly discusses a related literature review of spectrum auctions both in general and in the Asian market. Section 3 contains notes on data and methodology. Empirical results for the Asia 3G spectrum auctions and discussion are presented in Section 4. The conclusions follow in Section 5.

Literature reviews

Spectrum auctions

The spectrum is a scarce natural resource which is valuable. It belongs to national governments, and NRAs have a right to assign it to Mobile Network Operators (MNOs) commercially. McMillan (1995) pointed out that the spectrum is in demand not only for traditional uses such as broadcasting but also, increasingly, for new forms of wireless telecommunication. Four well-known methods of allocating spectrum have been used: first-come–first-served, lotteries, beauty contest and auction (Hazlett, 1999). As part of the broad reform of telecommunication regulation via liberalization, the 1990s are seeing a worldwide trend toward using auction.

The argument for auctions which is advocated by Coase (1959) is that the license will go to those who are able to profit most from using the spectrum by creating valuable services, as they will come with the highest bids. The opportunity cost of not using spectrum tends to decrease since it is likely to go to those who value it and to be used for most value application. Moreover, auctions generate wealth that can be used to pay for other government programs. Hence, auctions are a way to introduce more market-based prices for spectrum resource and more transparency than other methods do.

Although the first auction was introduced in New Zealand (1989) and followed by the UK (1993), a major development in government frequency allocation occurred in the U.S. in 1993 when Congress, in need of a new revenue source, required the FCC to auction spectrum, rather than using comparative hearings or other procedures. Economists had long favored auctions, rather than a political process that awarded spectrum to the politically well connected. Well-designed auctions lead to the greatest value use of the limited resource since those users will bid the most. Thus, auctions can lead to efficient economic outcomes. Furthermore, the government captures the rents associated with the limited spectrum, rather than rents going to lawyers or lucky lottery winners (Hausman, 2002, p.573).

Auctions have three important advantages. Firstly, they are a fast means of spectrum assignment compared to first-come–first-served, lotteries and beauty

contest. They minimize regulatory delay and inefficiency. Grünwald (2001) noted that assigning Personal Communications Services (PCS) licenses by comparative hearing took at least three times longer than auctioning the same kind of licenses, based on the studies from the US. Secondly, auctions are more transparent with clearly established rules compared to other methods. They also ensure that the process will avoid political favoritism. Lastly, auction has a tendency to assign the spectrum to those best able to use it. This is accomplished by competition among license applicants. Those firms with the highest value for the spectrum are likely to be willing to bid higher than the others, and hence tend to win the licenses (Cramton, 2002). Consequently, many economists have been advocating spectrum since the 1950s (de Vany, 1998 and Hazlett, 1998).

Unfortunately, the latter advantage is also a significant weakness. Auctions might help to put spectrum licenses in the hands of those who value them the most, but this valuation is based purely on financial grounds or on those who have deep pockets. Given the fact that under an auctioning regime, the assignment criteria are limited to the highest financial bid, auctions may prove to be inefficient in terms of failing to reflect the full potential of an applicant. Especially when it comes to auctioning broadcast licenses, this implies the risk that an applicant who offers a high-quality programming concept that might serve the public interest does not get a chance to broadcast this program, simply because he is outbid by another applicant with greater financial standing. Especially with smaller and minority-owned businesses, auctions can therefore turn out to limit access to the radio market and thereby to seriously restrict the freedom of broadcasting (Grünwald, 2001). Thus, Gruber (2001) raised a question about the limit at which spectrum fees are too high and constitute artificial entry barriers that drive operators out of the market or discourage further entry.

Although the assignment process encourages new entrants, they might resell their licenses in the secondary market or they may not activate the licenses. Those firms who get the licenses might have financial constraints post award, or they may not roll out the infrastructure and start their operation as they committed themselves to doing, since they have not enough funding for their investment. Moreover, a higher license fee might result in a lower number of firms sustained by the market. The market structure will then become much more concentrated with incumbents, and market growth will be lower. As Klemperer (2002) notes poor auction designs in some countries have facilitated collusion between firms and failed to attract entrants. This situation can be considered as inefficiency in the assignment method.

Asian spectrum auction

During 2000–2006, many countries in Asia allocated 3G spectrum to telecommunication service providers. The assignment approach can be categorized

into two major methods – auction and beauty contest. In the Asian market, Hong Kong was the first country to implement the 3G auction, in September 2001, and has been followed by many countries in subsequent years as shown in Table 1.

Table 1: 3G licenses assigned in Asia, 2000-2006

Country	Number of licenses		Name of Company	Value of winning bid for each license awarded	Year awarded	Duration of license (years)
	offered	awarded				
Hong Kong	4	4	Hong Kong CSL Limited Hutchison 3G HK Limited SmarTone 3G Limited Sunday 3G (Hong Kong) Limited	HK$ 288,812.12 HK$2,398,888.88 HK$1,388,888.88 HK$10,000.01	2001	20
Singapore	3	3	MobileOne (Asia) Pte Ltd Singapore Telecom Pte Ltd StarHub Mobile Pte Ltd	S$100,000,000 S$100,000,000 S$100,000,000	2001	20
Taiwan	5	5	Chunghwa Telecom Taiwan Cellular Far EasTone Taiwan PCS Asia Pacific Broadband	TWD10.17 Billion TWD10.28 Billion TWD10.16 Billion TWD7.7 Billion TWD10.57 Billion	2002	15
Indonesia	3	3	Indosat Excelcomindo Telkomsel	RP 160 Billion RP168 Billion RP 218 Billion	2006	10

Source: Author's compilation from several sources

Table 1 shows that fifteen licenses were assigned in four Asian countries during 2000-2006. The duration of licenses is 10 to 20 years. The bidding winner firms in Indonesia have the shortest period for network roll-out and service provision compared to other countries. The variation of final bidding price varies

from country to country. Hong Kong has the highest variation of value of winning bid for each license, while the lowest is in Singapore. Besides, the number of licenses offered is different. It may imply that the auction design is not one size fit for all. Each economic environment requires an auction design that is tailored to its special circumstances (Binmore and Klemperer, 2002).

Market efficiency, Auction and Winner's curse

Fama (1970) suggests that the market efficiency is a market where prices, at any given time, always fully reflect all available information. Then no investor has an advantage in predicting a return on a stock price or an asset, because no one has access to information that is not yet already available to everyone else. He identified the following the conditions as being sufficient for capital market securities' efficiency: no transaction costs in trading, all information is available cost-free to all market participants, and all agree on the implications of current information for the current price and distribution of future price of each security.

These conditions being sufficient for capital market efficiency does not, however mean that they are necessary. If a large enough number of investors has ready access to required information, and if no investors consistently make better evaluations of the information than others, the market might be efficient even if the three sufficient conditions are not fulfilled. High transaction cost might discourage making many transactions, but does not necessarily imply that prices will not reflect available information when the transactions do take place.

There are three identified classifications of the market efficiency: a weak form, a semi-strong form and a strong form. The difference among these forms depends on the degree of information. With the weak form of efficiency, all past prices of a stock are reflected in today's stock price. Therefore, technical analysis – a method of evaluating securities by analyzing statistics generated by market activity, such as past prices and volume – cannot be used to predict and beat a market. The semi-strong form of efficiency implies that the current price reflects not only the information which is contained in past prices, but all public information (including financial statements and news reports), and no approach can be used to achieve superior gains. The strong form means that the current price reflects all information, public as well as private, and no investors will be able to consistently find undervalued stocks.

The concept of market efficiency relates to the auction and winner's curse. A winner's curse is a financial anomaly or evidence of market inefficiency which reflects a price or return distortion in a market where assets are sold and bought. The auction winner can be said to be cursed in one of two ways: (1) the winning bid exceeds the value of the asset, so the firm loses money, or (2) the value of the asset is less than the expectation, so the winning firm is disappointed. The winner's

curse can be denoted as versions 1 and 2 respectively. Both versions reveal that all information plays an important role for a firm in making a bidding decision. Even if the winning bidder can make a profit in version 2 – as long as the profit is less than expected at the time that bidding was made, the winner's curse still occurs since the winner is unhappy about the outcome (Thaler, 1988).

In particular, Tse et al. (2009) state that the reactions of the stock market to the winners of the auctions has an interesting implication for the winner's curse. The success in acquiring an asset implies that the bidder has acquired an asset with potentially positive net present value. The stock market should view the acquisition favorably and the stock price of the winner should rise immediately following the successful acquisition of an asset. It is consistent with the study of Asquith (1983) which noted that there is a pronounced downward drift in the cumulative abnormal returns to the stocks of firms that are bidders in mergers. One interpretation of this evidence is that bidders overpay, and that it takes the market some time to gradually learn about this mistake.

Many studies investigate the winner's curse in various industries – for example, petroleum (McAfee and McMillan, 1987), highway construction (Athias and Nuñez, 2008), real estate (Tse et al., 2009) – and in financial markets such as treasury auctions and initial public offerings of equities (Levis 1990, and Chowdry and Sherman 1996). For the high-tech sector, Anandalingam and Lucas (2005) give an overview of why this sector is particularly prone to the winner's curse. The reasons are the uncertainty about future market conditions and a lack of experience with new technologies. The uncertainty about this type of technology may be significant, so that the bidders are not able to adjust their bids by taking into account the winner's curse.

In the context of the 3G license auction, two papers seek to identify the winner's curse, one looking at the UK 3G auction (Cable et al., 2002) and one looking at the German 3G auction and Sweden (Mackley, 2008). Both studies employ the event study. The former study finds that there is no evidence of winner's curse since positive as well as negative one-day wealth effects are observed among both winner and loser, and there is no lasting adverse market reaction to the winners, taken as a group – while the latter study reveals that there is at least short-term evidence of a winner's curse.

These studies reveal that stock market reactions enable us to investigate the winner's curse from the auction through the stock prices of the winner firms. A significant drop of stock price after the auction was made may be a signal for the winner firm that the acquired asset will be a burden for the firm growth in the long run. Theoretically, if the acquired asset does not generate positive net present value, shareholder value and firm value will decrease. Thus, this study will highlight how the 3G spectrum auction in Asia may directly impact the behavior of the stock market.

Data and Method

Data construction

This study focuses only on the 3G auctions that have taken place during 2000-2006 in four countries in Asia: Hong Kong, Singapore, Taiwan and Indonesia. The winner firms are mixed between listed and non-listed companies. Taiwan Cellular, Taiwan PCS and Asia Pacific Broadband in Taiwan and MobileOne and StarHub Mobile in Singapore are examples of non-listed companies during the auction period. In order to find whether a winner's curse exists during the 3G auction by event study, this study needs to evaluate the performance of the stock price on winner firms. Hence, non-listed companies are excluded in our sample. Historical stock data are extracted from DataStream. These data contain closing prices which are adjusted for dividends, splits and rights during the period.

Method

The winner's curse will be investigated by comparing event studies across countries. In general, event studies measure security price changes in response to events (MacKinlay, 1997). A single event study typically analyzes the average security price reaction to instances of the same type of event experienced by many firms. For example, the event could be the announcement of a merger, stock split and regulatory change. According to these events, they will have unexpected changes (relatively large increase or decrease) in price of some assets like security prices over some periods. The event studies evaluate the security prices of the firms involved in the event, as shown in Figure 1.

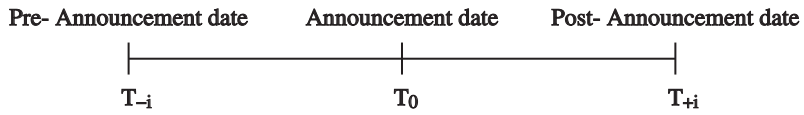

Figure 1: Time line of event study

Figure 1 means that we define an event window – a period over which the event occurs – and parameters are estimated. Then we start to calculate abnormal return due to the event by estimating a market model equation as shown in (1):

$$\ddot{R}_{it} = \alpha_i + \beta_i R_{mt} + u_t \qquad (1)$$

where $\ddot{R}_{it}$ is the expected returns on security i at time t, and β_i measures the volatility or risk of firm i, since it is compared with a market portfolio. R_{mt} is the

return of market index at time t and u_{it} is the error term.

This model shows that return on security i is linearly related to the return on a market portfolio, in this case the quoted stock of the 3G bidder, and the market return. The market model is not supported by any theory, but is an acceptable simplification of the more complex capital asset pricing model (CAPM) (MacKinlay, 1997). It assumes that the slope and intercept terms are constant over the time period during which the model is fit to the available data (Copeland and Weston, 1992, p.362).

We define the abnormal return as the difference between the actual return (R_{it}) and the estimated security return ($\widehat{R}_{mt}$). An abnormal return can then be calculated as:

$$AR_{it} = R_{it} - \ddot{R}_{it} \tag{2}$$

However, the one-day AR on its own is not enough to obtain a clear conclusion. In order to draw an overall conclusion for the event of interest, the abnormal return must be aggregated as the cumulative abnormal returns (CAR) (Mackley, 2008).

The accumulated impact of the event can be assessed by cumulative abnormal return (CAR) as shown in equation (3).

$$CAR = \sum_{t=\tau-i}^{\tau+i} AR_t \tag{3}$$

Since each stock may have a different event impact, one can justify this by weighting its cumulative abnormal return by its standard deviation. This results in a standardized cumulative abnormal return ($SCAR$) as shown in equation (4):

$$\widehat{SCAR} = \frac{CAR}{\hat{\sigma}} \tag{4}$$

where $\widehat{SCAR}$ is the standard deviation of the cumulative abnormal returns (adjusted for the forecast error: see Campbell, Lo, and MacKinlay (1977), Section 4.4.3). Then we use it as a test statistic. The null hypothesis is that the $\widehat{SCAR}$ is not significantly different from zero if the bidding price is the right price. The null hypothesis suggests that no abnormal return can be gained from the bidding process, in line with the semi-strong form of the market efficiency concept, while the alternative hypothesis which this study wants to prove true is that abnormal return can be negative if there is a winner's curse in the 3G auction.

Empirical results and discussion

In order to identify whether the winner's curse exists in the 3G spectrum

auction in Asia, the behavior of abnormal return (*AR*) and cumulative abnormal return (*CAR*) of the winning bidder is investigated around the auction date. If bidders do not fully account for the winner's curse, then the winning bid, on average, overstates the true value of the license. As a result, the winning bidders may earn a rate of return less than its cost of capital and the average excess rate of return to the winners would be negative. The empirical results are presented in this section as follows.

Table 2 shows the one-day ARs and wealth effect of winner firms. The one-day (column 1) is negative in two countries, Hong Kong and Taiwan, and positive only in the case of Singapore. Moreover, it gives a mixed result in Indonesia since Indosat has a negative abnormal return while the rest are positive abnormal returns. The positive abnormal return can be interpreted as firms having underpaid for their licenses.

Table 2: One-day abnormal returns and wealth effects of winner bidding firms.

Company	One-day abnormal return (1)	Market value ($ millions) at announcement date (2)	Wealth effect ($ millions) = (1)* (2)
Hong Kong			
Hong Kong CSL	−0.0017	7,908	−13.443
Hutchison 3G	−0.0211	34,704	−732.257
SmarTone 3G	−0.0086	608	−5.228
Singapore			
SingTel	0.0065	18,151	117.986
Taiwan			
Chunghwa Telecom	−0.0070	16,325	−114.275
FarEastone	−0.0098	4,572	−44.806
Indonesia			
Indosat	−0.0077	67.446	−0.519
Excelcomindo	0.0041	0.660	0.002
Telkomsel	0.0006	337.743	0.202

The wealth effect (column 3) in Table 2 represents how much the firm market value is reduced after the announcement date. We see that in absolute terms the 'winner in Hong Kong', Hutchison 3G, suffered the largest loss of market value, of over $732.257 million – whereas SingTel, the winner in Singapore, gained in market value after the announcement date. Its market value increased by $117.986 million. This would suggest that the mixture of positive and negative wealth effects depends on the examined country and firm.

Our result is similar to that of Mackley (2008), who found that most of the winner firms did under-perform in the German auction, so that after the end of auction the winners experienced a negative abnormal return. However, we cannot

compare the results of loser firms since no loser exists in the case of Hong Kong, Singapore and Taiwan.

Table 3 contains the 7-day, 15-day and 30-day CAR which show how long the curses stay with winner firms. The results show that the winner firms experience a significant negative cumulative return after the bidding announcement, for example Hong Kong CSL, SingTel and FarEastone. But this is not the case in Indonesia since the winner firms in Indonesia are faced with the curse for only 15 days; after that, they gain from getting the license. This is shorter than in the case of Germany.

Table 3: Cumulative abnormal returns 7, 14 and 30 days after end of auction

Company	Cumulative abnormal returns		
	7-day	14-day	30-day
Hong Kong			
Hong Kong CSL	−0.0045***	−0.0052***	−0.0068***
	(−2.9612)	(−4.1452)	(−6.6877)
Hutchison 3G	0.0143	0.0479***	0.076***
	(0.7132)	(2.7463)	(4.836)
SmarTone 3G	0.0143	0.0479***	0.076***
	(0.7132)	(2.7463)	(4.8358)
Singapore			
SingTel	−0.0025	−0.0022***	−0.0342***
	(−0.4903)	(−4.8109)	(−6.8772)
Taiwan			
Chunghwa Telecom	−0.00129	−0.00246	0.0007
	(−0.3467)	(−0.8772)	(−0.2239)
FarEastone	−0.0040***	−0.0070***	−0.0028***
	(−2.36711)	(−4.8670)	(2.3388)
Indonesia			
Indosat	−0.0067	−0.0233***	0.0217***
	(−0.9150)	(−3.4090)	(2.9089)
Excelcomindo	0.0092***	0.0189***	0.0048***
	(4.4051)	(9.3030)	(24.6820)
Telkomsel	−0.0145*	−0.0131*	0.0573***
	(−1.7817)	(−1.6652)	(5.9278)

Note : The numbers in parentheses represent t-statistics. ***, ** and * are significant at 1%, 5% and 10% level respectively.

The trends of abnormal return of each firm are shown in Figure 2. The figure shows each country separately. It reveals that although each firm is faced with negative abnormal returns, some companies perform better among the winner firms. For example, Hutchison in Hong Kong gains more positive cumulative abnormal return than others. Also, the market may have thought that on average the winner paid too much for its license in the initial period of the Telkomsel case, but

that sentiment was short-lived. In sum, there are only three out of nine winner firms that have negative cumulative abnormal returns 30 days after the end of auction.

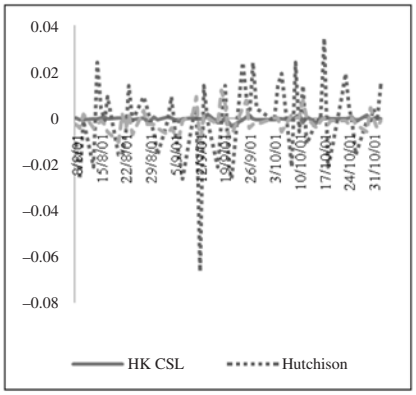

Figure1.1 Hong Kong

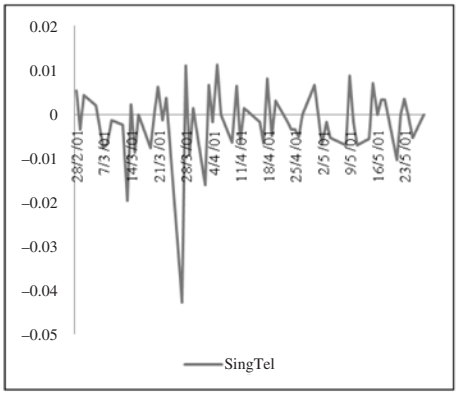

Figure 1.2 Singapore

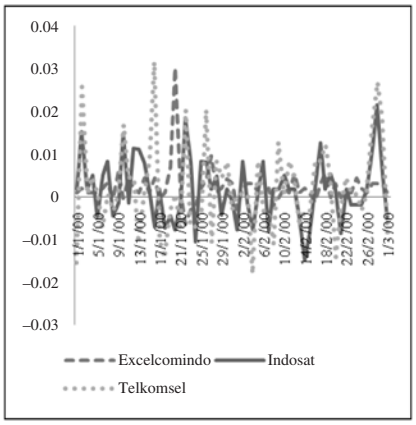

Figure1.3 Indonesia

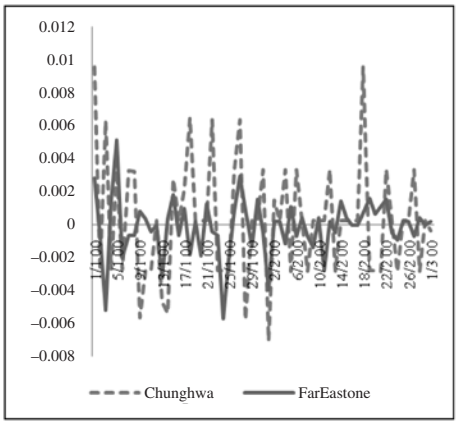

Figure 1.4 Taiwan

Figure 1: 30 days before and after the auction announcement[2]

These results suggest that although there are negative abnormal returns in the very short term, one possible reason is market imperfection. However, the negative abnormal returns almost disappear after fifteen days. The winner firms valued the licenses almost equal to the expectation of the shareholders and investors. Thus, the auction results do not make the winner firms disappointed. Another reason is the reserve price reduction by NRAs. NRAs in Asian countries are aware of the high reserve price according to Europeans' experience. Also, the main goal of 3G assignment is not a method of raising revenue for the government, but utilizing the spectrum with optimum efficiency. However, the long-term efficiency is still

in question, since NRAs need to monitor the inefficiency loss from their reserve prices in the long run in order to improve their reserve prices for the future auction and promote the development of the industry, in order to protect the interests of consumers and to maximize benefits to the economy as a whole.

Conclusion

A winner's curse is a financial anomaly or evidence of market inefficiency which reflects a price or return distortion in a market where assets are sold and bought. The auction winner can be said to be cursed either if the winning bid exceeds the value of the asset so that the firm loses money, or if the value of the asset is less than expected so that the winning firm is disappointed.

The previous literature reveals that stock market reactions enable us to investigate the winner's curse from the auction through the stock prices of the winner firms. A significant drop of stock price after the auction was made may be a signal for the winner firm that the acquired asset will be a burden for the firm growth in the long run. Theoretically, if the acquired asset does not generate the positive net present value, shareholder value and firm value will decrease.

This study has investigated the winner's curse in 3G auction in Asian countries over the period 2000-2006 through the behavior of the stock market. In the Asian experience, Singapore was the first country that issued 3G licenses by using the auction method in 2001. Currently, there are 4 countries granting 3G licenses to mobile operators – Hong Kong, Singapore, Taiwan and Indonesia.

The event study and market model are introduced in order to examine the winner's curse through the abnormal return of stock price. For one-day abnormal returns, there is a mixed result between positive and negative abnormal returns, while the cumulative abnormal returns show that the winners face the curse only for short periods after the end of the auction and then reverse to a positive signal. The short period of a negative abnormal return results from the reduction of reserve price and relaxation of the licensing condition. However, the long-term efficiency still needs more investigation by NRAs since an inefficiency loss may occur. The inefficiency loss may result from the bidding winners delaying their network roll-out or service provision. The reduction of reserve price does not guarantee that the granting of 3G license will be successful. The bidding winner may face market uncertainty and the difficulty of investment funding. Hence, NRAs need to monitor in order to improve the development of the industry and to protect the interests of consumers.

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NOTES

1. 3G is the third generation of mobile telecommunications, which features a maximum data rate up to 2-5 Mps and is expected to provide a variety of new and upgraded applications, including video telephony, multimedia mobile Internet, and global roaming services (Kim, 2005).
2. Hong Kong, Indonesia, Singapore and Taiwan auction dates were 19 September 2001, 1 February 2006, 11 April 2001and 7 February 2002 respectively.

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