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Auction Design with Speculative Resale

Harrison Cheng
Department of Economics,
University of Southern California,
Los Angeles, Ca, USA
Email: hacheng@usc.edu

Abstract. This is a report of my scientific activities while visiting KIER and the Yukawa Institute in February 2016. I present my research on optimal auction design with speculative resale, elaborating on the shorter presentation I gave at a symposium held at the Yukawa Institute on February 12. I also comment on the GESS/Kyoto conference held at the same Institute on February 11 that I participated.

I had an opportunity of spending one month at Kyoto Institute of Economic Research (KIER), Kyoto University in February 2016, while interacting with the Yukawa Institute for Theoretical Physics through its conference and programs. I have been quite familiar with people at KIER through many years of interaction in the past. I will focus on the interactions with the Yukawa Institute in the following report as it is an entirely new experience for me. This is a special occasion for me to experience the interdisciplinary research in Kyoto and Japan. Although I had plenty of such experience in US and Taiwan, it is the first time for me to see Japan from this angle. In one of the symposium held at the Yukawa Institute, I presented my research work in a half-hour talk. In this article, I will elaborate on the presentation, and provide more details about my research work on the optimal auction design.

1. GSEE/Kyoto

I participated at the GSEE/Kyoto 2016 conference held on February 11 at the Yukawa Hall. I learned that Yukawa Institute is a prestigious institute of Kyoto University on particle and fundamental physics, a field Japan has done very well in the past. The day also turned out to be an extraordinary day in which there was great anticipation of the announcement of the discovery of gravitational waves by the LIGO group in the US. I chatted with Prof. Misao Sasaki, director of the Yukawa Institute, about its significance before the conference. Prof Sasaki himself worked on the subject of gravitational waves. He was passionate about the topic and tried to enlighten me on its main ideas, only interrupted by the official beginning of the conference. I actually had learned about the impending announcement from CNN International, and read at some depth about it before I came to the conference. I can understand quickly what Prof Sasaki said in a nutshell. It was an exciting start of the day. Later I learned that a new research center for gravitational physics will be set up soon in the Institute.

The theme of the conference is global partnership on science education. It was attended by many first-rate researchers from the world. Many of them also have some experience in

promoting science education. The origin of the conference is credited to Prof Kazuo Nishimura, who has been concerned about the decline of science education in Japan, and has done a lot to promote science in the past. The success of the conference has a lot to do with his tremendous work. The first speaker of the conference was Juichi Yamagiwa, President of Kyoto University, explaining his work on human evolution. It was a good speech, and I learned a lot about the topic. But I must say he was overly ambitious trying to explain too much to non-experts within a limited time. The most rewarding talk for me in the conference is the one given by Akito Arima, former Japanese Minister of Education and former President of Tokyo University. He gave a brief history of the science education in Japan, as well as pointing out the most urgent problem at the present. There was great concern about the way humanity and social sciences will be treated in the future. He emphasized the importance of liberal education and the danger of its decline in Japan. However, some people seemed to put some of the blame on him during his tenure of the Minister of Education. This is a complicated topic I wasn't familiar with, and it certainly is perplexing to me.

The talks by Tai-Kai Ng from Hong Kong and Hong Ding from China on science education were quite inspiring, leading to many discussions in the panel session at the end of the conference. Some of the reforms attempted in China regarding education through less emphasis on exam scores are certainly relevant issues in Japan as well. However, there were skepticisms about their effectiveness. Some of the practices in Hong Kong presented by Ng on promoting interest and innovation in science seemed to generate more excitement. There were active discussions of the ways to promote science education, creativity and innovation in general during the panel session. There were questions raised about the lack of explorations or investigations on the part of the students in the classroom. One explanation has to do with the class size. Large class sizes seem to make the Q&A aspects of education impossible to improve. In my view, it is the lack of Q&A in education that explains the poor research skills of the students throughout Asia. Although class size certainly makes it difficult to have effective questions and answers among students and teachers, it may not be the only factor. There is a deeper and more difficult issue about Q&A that needs to be addressed. There is this idea of orthodox thinking that is embedded in the philosophy and practice of teaching. There is no attempt to teach students how to distinguish falsehood and truth or how to evaluate the importance of certain research activities. Innovation is not possible without raising questions about the current practice or thinking, and students are not trained to raise such questions at all. It may be that teachers themselves are not trained on this as well, and in this case they would not be able to teach this to the students. Emphasis on exam scores makes the Q&A less relevant in the practice of education. It is possible to change the exam questions to redirect the priorities in education, but this is not how exam questions are designed in reality. Over the years, the class size in Japan is getting smaller, but there is no sign that it is improving the educational quality in science. I think it will have little effect on the students' research skills if there is no change beyond the class size.

I also participated in the symposium the next day on advanced future studies. The topics of the symposium are rather diverse and spread over many areas. Alexander Vikman from the Czech Republic talked about dark energy and dark matter and the great universe. It was very informative, but I never learned what is dark energy. I later checked out the term in the internet, and it seems that no one really knows what it is, and the term is rather speculative. It certainly updated my little knowledge about physics and astronomy. I gained more updated knowledge about particle physics from the interesting talk by Maw-Kuen Wu from Taiwan. They are really great researchers. In one of the sessions, I presented my research on the

effects of collusion and speculative resale in auctions, and the general issue of auction design. In the short 30 minutes I had in giving my talk to non-experts, I presented no equations, even though I was ready for them. In the following, I will try my best to explain to non-experts in verbal language what I have been doing in my recent research work.

2. Auction Design and Speculation

My presentation starts with the explanation of the importance of auction design and practice in modern economies. The determination of prices for many new products, new companies, artistic paintings often depends on auctions. This also applies to many products or services with unknown valuation, such as IPO pricing, or costs of highway construction. Like many countries in the world, the Japanese government has procurement auctions which are used to determine what it should pay for the expressway construction and maintenance. The role of auctions can only grow as new products and services proliferate in our modern information-based economy.

I used the government procurement auctions in Japan to illustrate the serious consequences from defective auctions. A 2002 Japan Times article stated "In its final report submitted December 6, Prime Minister Koizumi's advisory commission for privatizing four road-related public corporations called for a halt to runaway highway construction". The report warned against the "triangle of collusion" among "road tribe" legislators, related bureaucrats and public-works contractors, which has distorted Japan's political, economic and social structures and left a combined debt of 40 trillion yen on the books of the four toll-road operators. The 40 trillion yen debt owed by the public four corporations equals half of the government's 81 trillion yen general-account budget for fiscal 2002. It is more than 1.2 times the gross national income of Russia, $253.4 billion, according to the World Bank.

The highway construction and the collusion through bid rigging continues to this day. Recently, prosecutors and antitrust officials searched the head offices and local units of road-paving firms suspected of rigging bids for the repair of expressways damaged in the 2011 earthquake and tsunami. The main players in the bid-rigging were individuals handling sales and other matters at the local units of the industry's three largest road-paving firms — Nippo Corp., Maeda Road Construction and Nippon Road. They are alleged to have colluded with other companies and decided in advance which would submit the winning bid.

On average, the successful bids amounted to 94.77 percent of the contract prices budgeted by Nexco East, over 10 percentage points higher than the levels for similar contracts before the disaster, the sources said. This artificial higher cost does not even include the distortion from the budget determination process. It is widely recognized that Japan's high budget deficit has a lot to do with such high costs. One of the victims of the high deficit is the budget allocated for education and research.

Modern understanding about auctions has benefited from the optimal auction theory developed by Roger Myerson (1981). His work shows us how to find the private-value auction format that will yield the highest revenue for the seller. We will take this approach in our discussions here, using "optimal" to mean the auction that yields the highest revenue to the auctioneer. Myerson's theory only applies when the resale factor is not considered. The importance of the resale factor has been known for a long time since the work of Haile (2001). Not much progress has been made since then. As the resale factor is often pervasive, my research focuses on how to find the optimal auction when resale is allowed. It is known that the resale factor may change the bidding behavior from private-value auctions to common-

value auctions (Cheng and Tan (2010)). The general extension is quite complicated, and I concentrate on a simpler framework in which only the presence of speculators is considered. All buyers other than the speculators have symmetric and independent valuations on the objects for sale. In our model, there is no loss of generality in assuming that there is only one speculator.

One difference in our approach from Myerson's work is that I consider the (indirect) bidding mechanisms, while he uses direct mechanisms. A direct mechanism is one in which buyers report their true valuations, and the payment rules are designed to make this incentive compatible. Theoretically, this is possible to do, and Myerson (1981) then determines who should be the winner based on the reported values in order to maximize the revenue of the auctioneer. In general, the buyer reporting the highest value is not necessarily assigned the winner in order for the auction revenue to be maximized. The optimal auction found this way is often impractical to implement, although it greatly enhances our understanding. The (indirect) bidding mechanism that I consider here is just the mechanism used in practice. Buyers report the price (bid) they are willing to pay. These prices may not be the same as their total willingness to pay. The winner of the auction is the one who has the highest bid. The winner may pay a price which need not be the highest bid. If the winner pays the highest bid, we refer to this as the first-price auction. If the winner pays the second-highest bid, we refer to this as the second-price auction. For simplicity, our discussions will be focused on sealed-bid auctions with one single bid from each buyer. The results can be extended to dynamic auctions in which bids are submitted over time in a competitive fashion as in many antique or artistic painting auctions.

In a bidding auction, the winner is always the buyer with the highest bid. The auctions differ only by payment rules. In principle, the winning price can be any function of the submitted bids. In our approach, we essentially fix the winning rule, and find a simple payment rule to be optimal.

There are two stages in the model I will use. In the first stage, the auction payment rule can be any function of all the submitted bids. I assume that during resale, the winner of the first-stage auction uses an optimal auction of Myerson (1981) to sell to the losers and the game ends at the end of the second stage. Thus a buyer has two chances of winning the object: in the first stage auction or during resale. A buyer may bid lower in the first stage, preferring to buy during resale if he or she finds that to be more profitable. Between the first and second stage auctions, the auctioneer may decide what information to reveal about the submitted bids in the first stage auction. We make the assumption that only the winning bid is announced at the end of the first stage and before the beginning of the second stage. This assumption may seem impractical, but it is a useful theoretical assumption. It simplifies the equilibrium analysis, and we don't expect the bid revelation policy to affect the ranking result we will present here. This point will be further discussed at the end of the article.

One useful comparison between Myerson's result and the result here in the context of symmetric auctions with a speculator is that his result becomes the search for an optimal reserve price using second-price auctions, while my result shows first-price auctions to be optimal for any given reserve price.

3. Dominance of First-Price Auctions

First, we will compare the revenues of first-price and second-price auctions with no reserve price. The revenue of a first-price auction with resale is unique and can be computed

in a relatively simple formula given in Cheng and Tan (2015). There are many complications dealing with second-price auctions with resale. Truthful revelation is no longer a dominant strategy. In general, there are infinitely many equilibria as shown in Garratt, Tröger, and Zheng (2009). The multiple equilibria are due to the possibility of engaging in collusive bidding which can take many different forms with different revenues. These collusive equilibria typically have overbidding as well as underbidding, and one bidder is able to bid higher, wins the auction while paying very low winning price. It is not always true that the first-price auction yields higher revenue than all the possible second-price auction revenues with collusive bidding. However, we can show that if a second-price auction revenue with collusive bidding is higher than that of the competitive equilibrium, then it can only be achieved by lowering the total payoff of the buyers, and the buyers would not implement such collusive bidding behavior. Hence subject to the unlikely adoption of such collusive equilibria, we conclude that first-price auction revenue is higher than second-price auction revenue. This result is not affected if the reserve price is other than zero.

To explain the dominance of the first-price auction revenue in general, it is useful to consider a theoretical auction format that will throw insights into the question. The winning rule is always the same: the highest bidder wins. When a buyer wins the auction, he pays a convex combination of the highest bid and the second-highest bid . We call this hybrid auction. Let t be the weight on the highest bid. When t=1, it is the first-price auction, and when t=0, it is the second-price auction. In general the equilibrium can be shown to be unique when t >0. We can examine the auction revenue as a function of t. For any given t >0, we can calculate the auction revenue using a formula very similar to that of Cheng and Tan (2015). It can be shown that the revenue is increasing in t, meaning that the revenue is the highest when it is a first-price auction. The intuition behind this result is that as t becomes higher, the winner pays a higher amount after winning with the same submitted bids. As a result, buyers will bid lower. When the buyers bid lower, the speculator derives less benefit from resale. The speculator then participates less often in the first-stage bidding. When the speculator is less active, the competition among buyers is reduced, and therefore the revenue is lower. In other words, the revenue effect comes through the role of the speculator.

The ideas that I use in the last paragraph apply to the revenue comparisons of first-price auction and any other auction payment rule that is bounded above by the highest bid. If the payment rule is not bounded above by the highest bid, we rely on a normalization effect. We can deflate the payment rule by a constant. We can show that this deflation has no effect on the bidding behavior and the auction revenue. As a result, our revenue comparisons are not affected if we normalize the payment rule so that the payment of the winner is bounded above by the highest bid. From the foregoing discussions, we conclude that the first-price auction is the optimal one among all the payment rules given any reserve price, a very dramatic conclusion.

We can now say something about the bid revelation policy. The assumption of revealing only the highest bid is impractical when the winner pays the second-highest bid in second-price auctions. To make this theoretically consistent, the payment amount can be delayed to the end of the game, as the resale mechanism can go ahead without this piece of information, which is not relevant in the determination of the optimal resale auction.

It is important to know what happens when more bids are revealed by the auctioneer. The information revelation may give the winner exploitation opportunities during resale. It also may induce the buyers to hide their true value by using random bids (or mixed bidding strategy) to avoid this exploitation. Once we allow mixed-strategy bidding, equilibrium

revenue determination becomes a potentially complex problem. This is an issue that needs to be resolved. Our current understanding or conjecture is that a different bid revelation policy will yield the same conclusion.

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