Auctioning Rough Diamonds:
A Competitive Sales Process for BHP Billiton's Ekati Diamonds

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Abstract

We describe a new approach for selling rough diamonds through competitive auctions. The classical approach of De Beers—giving each customer a bag of stones and a take-it-or-leave-it price—worked well in near monopoly circumstances, but is ill-suited for competitive producers. Competitive producers, like BHP Billiton, benefit from getting the diamonds to those who value them the most. Beginning in 2008, BHP Billiton introduced a simple auction process to assign its Ekati diamonds to the highest bidders at competitive market prices. A Spot auction, ten times per year, is used to establish prices for each of nineteen deals of diamonds grouped by size, color, and quality. A Term auction allows customers to lock in a long-term supply commitment at prices indexed to future Spot auctions. A Specials auction, two or three times per year, prices large stones. The auctions use an ascending-clock format in which prices increase for each product until there is no excess demand. This approach allows customers to discover market prices, while managing portfolio and budget constraints. The approach has proven remarkably successful in pricing and allocating the mine's output even in the face of the global financial crisis.

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1   Introduction

BHP Billiton produces approximately six percent of the world's diamonds from its Ekati mine in the Northwest Territory, Canada. These rough stones are then sold through various channels primarily in Antwerp, Belgium. This paper discusses the previous sales process and analyzes the transition to the current sales process. We address both the Spot market and a longer-term market intended to capture a premium for supply regularity.

Three problems with the previous sales process were: 1) an excessive reliance on the price book for pricing, 2) the limited ability of customers to express preferences for quantities and types of stones, and 3) failure to capture a competitive premium for supply regularity. These shortcomings suggest that the allocation of stones may not have been best, and the pricing of the output may not have been competitive.

Beginning in January 2007, we worked with BHP Billiton to develop and implement a simple auction approach to improve the assignment and pricing of the mine's output. The auction follows the same sales cycle as before and a similar bundling of the stones into a set of 19 "deals" (products) grouped by

size, color, and quality. The difference is that the auction lets the customers compete directly for quantity using either a uniform-price auction or an ascending-clock auction. Both auction formats are simple market mechanisms, commonly used to find the value-maximizing assignment and competitive prices of the goods. By putting the diamonds in the best hands, BHP Billiton better satisfies the needs of its customers and improves sales revenues from the Ekati mine. Customers focus on their business and being more competitive, rather than on efforts to please the producer to receive a more favorable allocation.

To provide supply regularity, a Term auction is offered periodically in which customers bid a differential to the Spot price for each deal for terms of one year or more. An ascending-clock auction was chosen to foster price and assignment discovery. This enables each customer to build a portfolio of quantity commitments across the deals. Each customer pays the same price premium or receives the same discount for locking in supply and demand long term for a particular deal.

Finally, two or three times a year, large stones are sold in a simultaneous ascending-clock auction, called a Specials auction. Each lot is a single stone or a group of stones of like size, color, and quality. The ascending-clock format is used, since price discovery is especially important for these exceptionally rare and valuable stones.

Educating customers to the new approach was an important step in the transition. Some resistance was experienced from Regular customers. Resellers, especially, felt they had the most to lose if the inefficiencies of the previous process were eliminated. BHP Billiton carefully managed customer relationships during the transition, and developed support for the approach. The main advantage is to customers with high values. These customers find it easier to acquire both the type and quantity of stones they desire.

The new approach combines many aspects of the previous sales process with well-tested and understood auction methods. Most importantly, the new approach is a more transparent and market-responsive sales mechanism. Customers express their preferences directly and credibly through their bids in competitive auctions. The transition was carefully managed to gradually introduce new methods and build customer support. The transition entailed little risk because the demand-side for rough stones is competitive. Individual customers do not benefit by boycott or exit, since there are many other manufacturers and resellers that desire to be BHP Billiton customers. Moreover, it will be BHP Billiton's best customers—those with high values—who benefit the most from the new approach, since these customers are able to win the quantities and types of stones they most desire.

2 Empirical evidence of the success of the approach

Vivid evidence of the success of transparent auctions is seen by comparing rough diamond price indices from several public sources. This is done in the following figure for the period 2007 to the present. To make the indices comparable, each index has been scaled so January 2008 = 100.
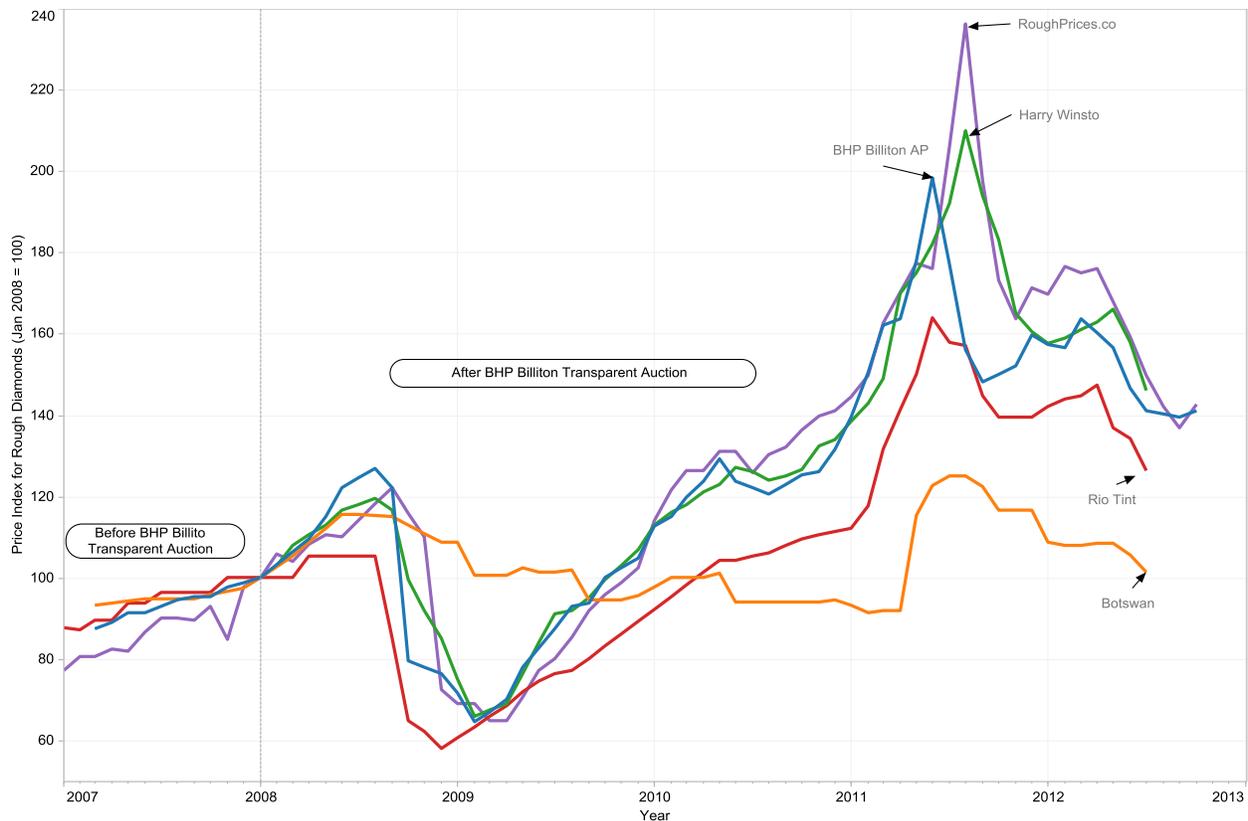
Sources: blue: BHP Billiton Customer Report 141; green: Harry Winston Investor Presentation September 2012; red: Rio Tinto Diamonds and Minerals 12 September 2012; orange: Botswana Financial Statistics September 2012, tab 6.5, purple: RoughPrices.com.

Notice that all the indices are about the same in 2007 before the introduction of auctions. Then in 2008 BHP Billiton introduced transparent auctions. After that BHP Billiton becomes the price leader. The other indices either lag behind the BHP Billiton index by one month (Harry Winston, operating a modified Sight system with market pricing, or RoughPrices.com) or are typically below BHP Billiton (Rio Tinto and Botswana, operating traditional Sight systems). Importantly, the revenue advantage of our approach is even greater when one recognizes that most of BHP Billiton sales are at a price premium above the BHP Billiton API. The price premium is set at term auctions (about one per year) in which customers lock in quantity shares for particular categories of stones. Typically the price premium is between 1 and 4 percent of the API.

Consistent with the traditional sales approach of De Beers, the Botswana price index is much flatter. For most of the 5 years it is significantly below the BHP Billiton index suggesting a significant revenue loss by Botswana. The exception is the late-2008 to late-2009 period during the global financial crisis, when the Botswana index is significantly above the others. However in this period BHP Billiton was able to sell the entire output of Ekati and had revenues well above De Beers, who markets the Botswana diamonds, despite its much smaller size—a high price is of little value if it results few sales. Overall, the transparent auction methodology has provided superior returns for BHP Billiton and served as an important benchmark for price discovery for the market as a whole.

3   A brief history of the diamond industry

BHP Billiton is the fourth largest source for rough diamonds. De Beers currently has about 45% of the market. ALROSA (Russia, 20%) and Rio Tinto (Australia, 8%) are the other two large rough diamond producers. Market demand is highly fragmented; there are over 1,500 potential customers for rough diamonds.

Until the 1990s, De Beers controlled the vast majority of the market and established the structure of the market. In the 1880s, Cecil Rhodes started consolidating control of the major diamond mines which at that time were all located in South Africa. In the late 1920s, Ernest Oppenheimer took control of De Beers and established a central selling organization called The Diamond Corporation.

The Diamond Corporation offered rough diamonds to each customer in a box that would contain an assortment of rough diamonds picked by De Beers for the individual customer. The box must be accepted or rejected as a package. If the box is rejected, De Beers may not invite the customer back for some years if ever. De Beers priced these boxes at 25% below its estimate of market prices, but varied price and quantity to smooth price changes and to reward and penalize behavior. A customer found to be buying diamonds coming from outside the cartel might be penalized by being offered a box with poor quality goods at high prices. The message, which was sometimes reinforced verbally, was stop cheating on the cartel or be excluded from the direct benefits of it.

De Beers organized the demand side of the market this way to restrict polished diamond supply. Manufacturers and resellers had strong incentives to continue to participate in the cartel. How the rough diamonds were allocated to customers was less important to De Beers than assuring that overall supply was restricted and demand was growing.

Customers did their best to convince De Beers that they should get additional quantity and higher quality. This was challenging because all customers wanted more supply. Competition focused on gaming the opaque De Beers allocation process and staying in favor. One possible result of this gaming may be the high number of customers.

Over the years, De Beers had to cope with discoveries in Russia, Zaire and Angola which it did by including these new players in its cartel. In the 1980s and 1990s, De Beers faced challenges as some mines in Zaire and Australia elected to sell directly to customers. This was the advent of open competition in rough diamond supply. De Beers stopped restricting the supply of the stones that these mines specialized in resulting in a steep price drop. This was effective at getting Zaire to rejoin the cartel, but others stayed independent.

In 1998, when the Ekati diamond mine in Canada was opened, BHP Billiton adopted many of the practices that were customary in the industry, but did not join the De Beers cartel. In 2004, BHP Billiton began offering portions of its supply by sealed tender. In 2008, BHP Billiton began selling more than half of its supply by ascending-clock auction and the rest in sealed-bid uniform-price auctions. This revolution in market pricing has benefitted BHP Billiton and its best customers. The approach has performed well throughout the global financial crisis. The auction approach enabled BHP Billiton to quickly adjust to competitive market prices. This allowed it to keep sales volumes high when prices fell. In early 2009, BHP Billiton increased revenues while De Beers revenue fell. Customers were allowed to bid for long-term supply contracts for the goods they wanted. Now more producers are considering the BHP Billiton model—a model of pricing and assigning diamond supply in a transparent competitive process.

4   Outline of the previous BHP Billiton sales process

Like De Beers and other rough diamond producers, BHP Billiton had a proprietary price book that was used in setting prices. The output from the Ekati mine is sold on a 5-week cycle, 10 times per year. Each shipment is roughly $60 million, excluding large stones ("Specials") which are grouped for 2 or 3 sales per year. The rough diamonds are sorted by size, quality, and color into about 4,000 price points— each with a price per carat in the price book. The diamonds are then grouped into about 19 deals. Each deal is an aggregation of closely related price points. There are about 200 price points in each deal.

About 15% of the total quantity, in value terms, were removed for Northwest Territories (10%) test polishing and direct sales to retailers (5%). The remaining stones were sold in Regular (50%), Elite (20%), and Tender and Window (15%) channels. Each of the deals was split into parcels, where each split is a representative sample of the deal.

There were 8 Regular customers. Each received about 10 parcels per cycle and paid the total price for all parcels, based on the price book. This was the invoice price and was the only price that the Regular customer saw.

There were between two and four splits of each deal for the Regular customers. This was done to get comparable market feedback. Feedback was the actual or estimated sales price reported for each parcel by the regular customers. Reports were received after about ten days. Feedback impacted the price book and whether the Regular customer was dropped. BHP Billiton targeted a long-run customer margin of a few percent in setting the price points. Deal-level price information was hidden from customers to avoid cost-plus feedback, in which the customers simply report, say, 4% more than cost.

Elite customers were like Regular customers (indeed 3 of 9 were Regular customers), except they paid a premium over price book. The premium was bid for a two-year period. Unlike Regular customers, Elite customers could reject the goods. On average the Elite customers paid significantly more than the price book.

About 20 parcels were tendered, each valued at about $200k-$500k. There was a secret reserve price based on the price book. The bidder examined some subset of the parcels, and submitted a sealed bid on each desired parcel within 24 hours of viewing. Viewing typically took about three hours. Parcels receiving bids above the reserve price were awarded to the highest bidder at the price bid. Tender sales were several percent above the price book. Window sales, which were negotiated, also were about several percent above the price book. Tender and window sales were by invitation only. Consistently poor performers were not asked back. Bidders learned the high bid on lots they bid on provided they won at least one parcel; otherwise, they learned nothing.

A final source of price information was from the sale prices of polished stones. BHP Billiton polished and sold some of the stones in the Canada Mark program. The rough to polished data provided valuable information for the pricing relationships in the price book. Sales to Northwest Territory based customers were priced at market prices. A premium was charged as the deals were tailored for polishing in the Northwest Territory.

5   Problems with the previous sales process

There were four problems with the previous sales process.

First was the heavy reliance on the price book to set price. It was difficult for BHP Billiton to know if it was getting the best price. This problem was somewhat mitigated by using several methods to adjust the price book: 1) Regular customer feedback, 2) Elite bids, 3) tender and window sales, and 4) polished

outcomes. Still there was a potential gaming problem of the Regular customer feedback. A customer may under-report in the hopes that doing so will lead to better prices in the future. Alternatively, a customer may over-report in the hope of getting more goods in the future. Entry and exit from the Regular channel provides a relatively weak and discontinuous incentive for truthful feedback. Regular customers were only rarely swapped out. Moreover, the criteria for becoming and remaining a Regular customer were unclear.

The second problem was that customers, especially Regular customers, had little means of expressing preferences for stones—both quantity and type. BHP Billiton fixed quantities for Regular customers. There was little means to assure that the goods were going to the right parties.

The third problem was that BHP Billiton failed to capture a premium for the supply regularity that its Regular customers enjoyed.

A fourth problem was the complexity and non-transparency of the sales process. The incentives in each of the main channels were complex. Bidders wanting more quantity must participate in more channels—or even demerge to become two customers—rather than directly expressing larger demands. The process lacked transparency, especially in the Regular channel, where BHP Billiton set both prices and quantities.

## 6 A Spot market in which customers bid directly for quantity

We now consider a market in which bidders directly express preferences for various quantities. We begin with a Spot market to be held at each cycle. This is the cornerstone of the market. Under this approach, the diamonds are awarded to the highest bidders at market prices. The approach is simpler than the previous sales process. Most importantly, it creates value by seeing that the diamonds are put in the hands of customers with the highest values. In addition, customers can limit quantity risk—the possibility of winning more or less than desired—first, through a complementary long-term market and second, through their bidding strategies in the Spot market. In this way, BHP Billiton can maximize the value to its customers and thereby the revenues from the Ekati mine's output.

First consider a single deal. All customers for the deal compete together. This includes all the Regular and Elite customers, as well as many other customers with membership in the Responsible Jewellery Council. A representative split or sample of the deal, typically between 1/12 and 1/6 depending on the particular deal, is put in a parcel for viewing. Bidders know how many splits there will be for this deal (e.g., 7) and how they will be divided between the Term and Spot market (e.g., 4 splits in Term and 3 in Spot). The viewing parcel is selected carefully to be the most representative of the entire deal. Each customer views the parcel and then submits a bid schedule, indicating its demand for the deal with one or more price-quantity pairs. Price is the price per carat (e.g., $730/ct). Quantity is the number of splits desired (e.g., 2 splits) with price adjusted for quality based on the price book (e.g., a discount of 1.2% for a split of slightly lower quality than the viewing parcel). Each customer has a maximum quantity for the deal: 3 splits for deals with 5 or more splits in the Term market, 2 otherwise.

There are a number of possible auction formats within this structure. We describe three: the uniform-price auction, the pay-as-bid auction, and the ascending-clock auction.

6.1 Uniform-price auction

The auctioneer aggregates all the bid schedules to form the aggregate demand curve, as shown below.
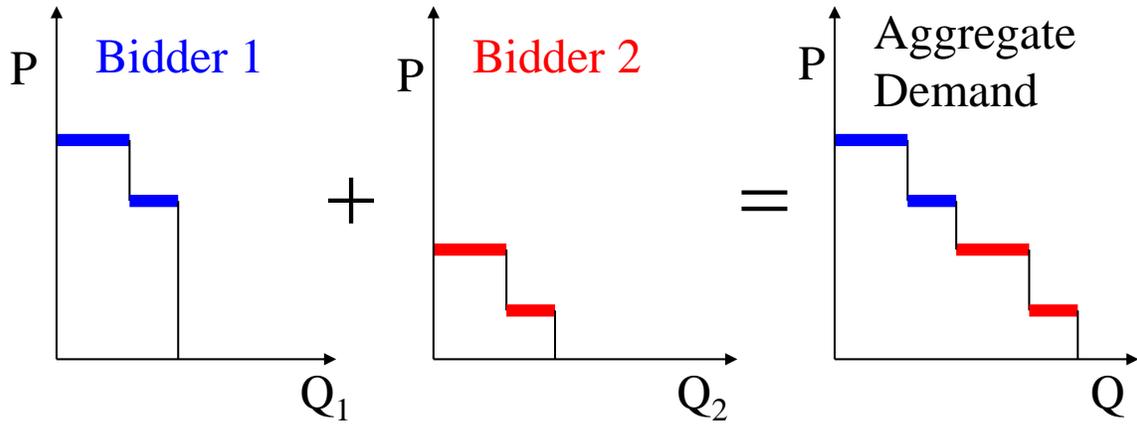
The aggregate demand is then crossed with the supply curve. The intersection of supply and demand determines the market clearing price, as shown below.
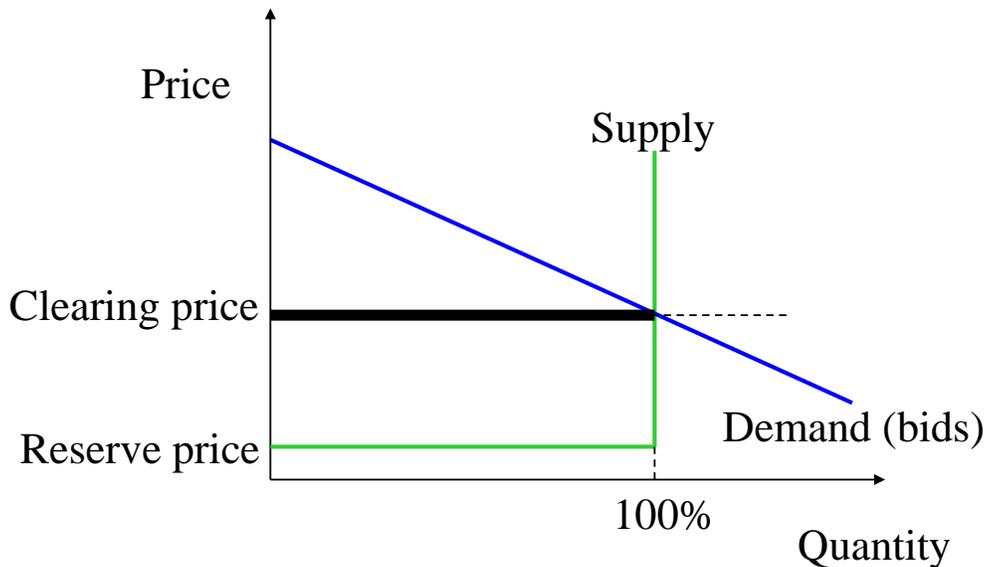
All bids above the clearing price win and pay the clearing price. Quantity for a bid at the clearing price may be subject to a random tie break, so the total sold equals 100%. In addition, bidders are aware that the quality and quantity won may vary by a few percent due to the discrete nature of the product sold. Finally, the supply curve reflects the reserve price or, more generally, the desire of the seller to postpone sales if prices are too low. Goods not sold in the current auction, as a result of the supply curve, are sold at later auction prices once market prices exceed the reserve price. In the event that supply and demand intersect over a range of prices, the clearing price is the highest such price; in the event that supply and demand intersect over a range of quantities, the clearing quantity is the largest such quantity.

The figure below gives an example focusing on two bidders, Blue and Red. The table on the left gives the aggregate demand curve, as well as the bids of Blue and Red. On the right, we see that the demand curve intersects with supply at $560. Both bidders' higher bids are accepted in full. Blue's lower bid at $560 is "on the margin." It is partially accepted (rationed), resulting in winnings of 35% for Blue and 25% for Red. Both pay $560/carat for their shares, appropriately adjusted for quality differences.

P	Σ Q	Q	Bidder
>575	<40%		Other
$575	65%	25%	Blue
$570	90%	25%	Red
$560	105%	40%	Blue
$555	120%	40%	Red
<550	>120		Other
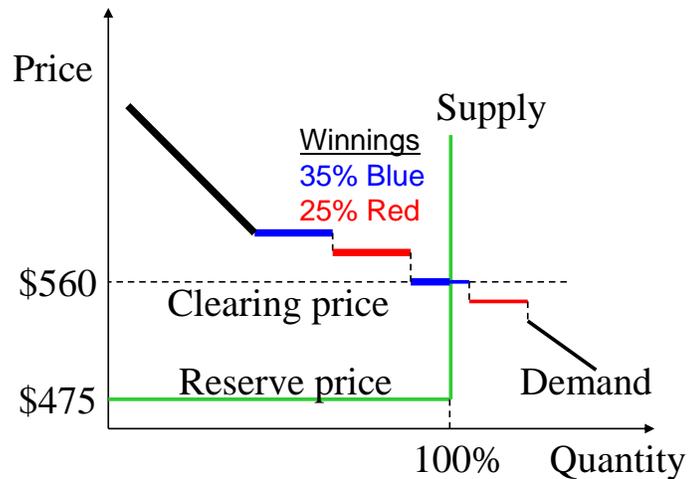
The uniform-price auction is the most common method for selling a divisible good. In this setting, the use of the price book to adjust splits for quality makes the deal a divisible good.

The frequent use of the uniform-price auction stems from its many desirable properties. Absent market power, each bidder has the incentive to bid its true demands, and the resulting assignment maximizes the total value of the goods. In the long-run, such an outcome should maximize BHP Billiton's revenue from the mine.

Bidders like the fact that they do not ever pay more than the market price for the quantity won. Moreover, uniform-pricing lets the bidder better manage quantity risk. The bidder can bid its full value, knowing that it will only be required to pay the clearing price. In this way and through the long-term market, the bidder guarantees that it wins its desired minimum quantity. Both the bidders and BHP Billiton benefit from this reduction in quantity risk.

When bidders have market power, the uniform-price auction has incentives for demand reduction, causing each bidder to bid less than its true demand. The result is lower auction revenues and reduced auction efficiency. However, given the competitive market structure on the demand side, this is unlikely to be a problem, and in any event the reserve price provides substantial protection both from demand reduction and collusion.

6.2   Pay-as-bid auction

The most common alternative to the uniform-price auction is the pay-as-bid auction. The only difference between the two is the pricing rule. In a pay-as-bid auction, all bids above the clearing price win, but the bidder pays its bid for any quantity it wins, as shown below.
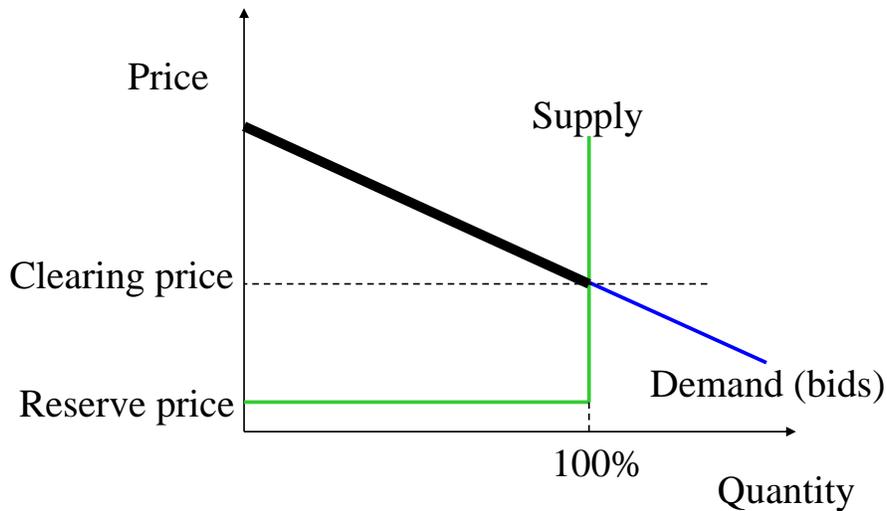
At first glance, it may appear that the pay-as-bid auction generates more revenue than the uniform-price auction, since the bidder pays its bid, which is at least as high and typically higher than the clearing price. This, however, is not the case. The pricing rule greatly impacts the bidding behavior. The figure below shows typical bid curves for a bidder with the true demand in black. Under pay-as-bid pricing (red), the bidder guesses the clearing price and tries not to bid much above it. Under uniform-pricing (blue), the bidder bids closer to its true demand, although the bidder does increasingly shade its bid for larger quantities, optimally taking account of its impact on price.
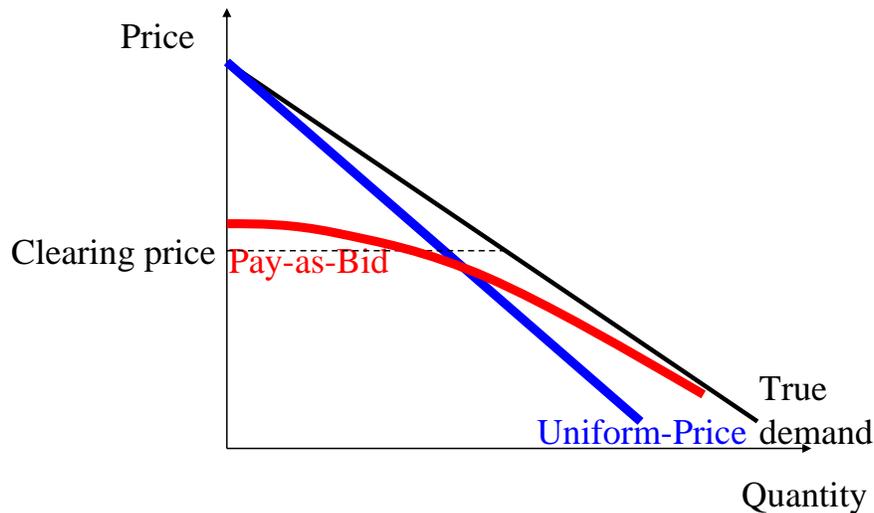
As a result, revenues may be either higher or lower with pay-as-bid pricing than with uniform pricing. Despite a vast theoretical, empirical, and experimental literature, results comparing revenues under these two pricing rules are decidedly ambiguous. What is known is that quantity risk is much greater under pay-as-bid pricing; whereas, price risk is greater under uniform pricing. The reason is that the aggregate demand curve under pay-as-bid pricing is much flatter than under uniform pricing. As a result with pay-as-bid pricing, a modest change in a bidder's bid price can have a large impact on the quantity the bidder wins.

To reduce quantity risk, the pay-as-bid auction can be extended to include price-taker bids. These bids are awarded in full at the average sales price that is bid competitively. With this extension, customers can guarantee minimum quantities, as in a uniform-price auction.

There is some experimental evidence that in repeated auction contexts, like this one, that pay-as-bid pricing is more vulnerable to collusion, because the bidders have a stronger incentive to coordinate on a price, and thereby reduce the amount of money "left on the table"—the amount bid in excess of the clearing price.

In 1998, the US Treasury switched from pay-as-bid pricing to uniform pricing, after many years of study. The switch was motivated from the pay-as-bid auction's vulnerability to the "short squeeze," where one bidder attempts to corner the market of a particular product. The short squeeze is not an issue here, since short sales are not allowed, the BHP Billiton sales are only a fraction of the total market and a cap was imposed on how much each customer can win of each Deal (40-50%).

Finally, the uniform price rule has more resilient efficiency in the face of highly variable pricing such as that experienced during the recent financial crisis. The pay-as-bid auction provides a strong incentive to use ex-ante expectations to try to guess the final price. If the final price is far from expectations, the goods will go disproportionately to the best guessers as opposed to the customers who value the goods the highest. The uniform price auction continues to achieve high efficiency in this circumstance and there is little advantage to being a good guesser.

6.3   Ascending-clock auction

In recent years, thanks in part to the power of the Internet, it is common to sell divisible goods using an ascending-clock auction. This is simply a dynamic version of the uniform-price auction. Rather than submitting a demand curve at a single time, the bidder submits demands over a sequence of rounds. The auctioneer announces a low starting price and the bidders respond with the quantity desired at that price. If there is excess demand, then the auctioneer raises the price and the bidders again respond with their demands at the higher price. The process continues until there is no excess demand. Each bidder then wins its bid quantities at the clearing price, just as in a uniform-price auction. The "clock" is simply the price, which ascends until supply and demand balance as shown below.
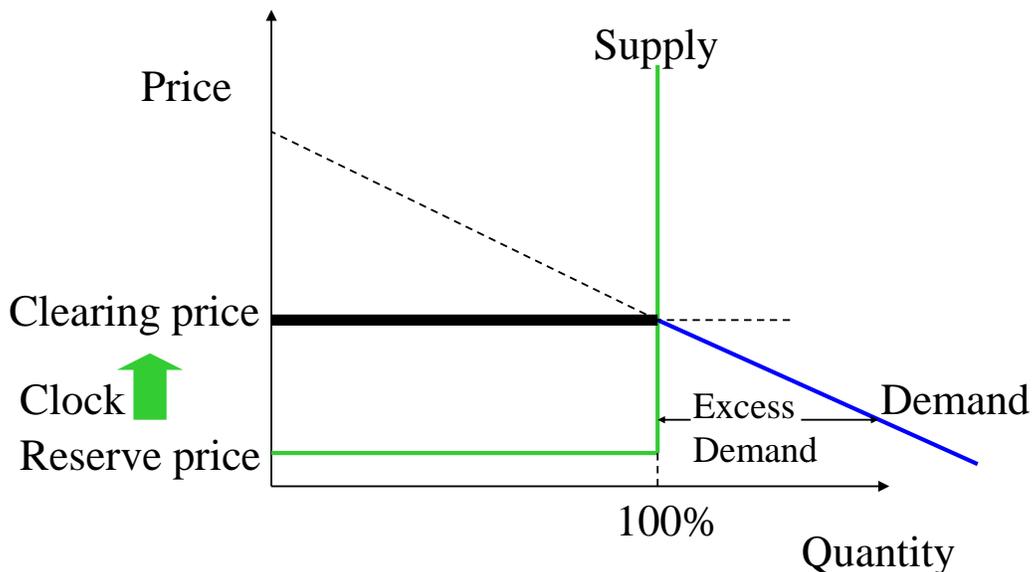
The clock auction has all the advantages of the uniform-price format, and in addition, allows for better discovery of the market price via iterative feedback. Price discovery is often important in contexts like this one in which there is common uncertainty about the value of the goods, and each bidder is estimating value.

To promote price discovery, there is an activity rule that prevents a bidder from increasing its demand as prices rise after an initial few rounds. Bidders can only maintain or decrease their quantities as prices rise. Thus, each bidder must bid in a manner consistent with a downward sloping demand curve.

Clock auctions of this sort can be conducted in a matter of one to four hours over the Internet. A technique called intra-round bids typically is used to retain most of the advantages of a continuous price clock, and yet allow the auction to be conducted in, say, six to ten rounds.

A bidder, especially if it desires only a small quantity, may prefer to submit all its bids at one time. Such "proxy bidding" is accommodated easily, guaranteeing that bidders will not be discouraged from participating as a result of a lengthy (or overnight) bidding process. In particular, this allows a bidder to enter bids all at the start, if the bidder does not desire to take advantage of price discovery. A few bidders choose to bid in this simple way.

Collusion is mitigated by the reserve price and an information policy that limits the bidder's information to the aggregate demand at the end of each round. In particular, bidders do not learn the quantity bid by individual bidders and do not learn the identity of the other bidders for particular deals during the auction.

6.4   Handling multiple deals

It is straightforward to extend the single-deal format to 19 deals.

With the sealed-bid methods (uniform-price and pay-as-bid), the bidder simply submits bid schedules for each of the deals. With multiple deals, quantity risk may be more of a factor, especially if all deals are auctioned simultaneously. This would favor uniform pricing, which lets the bidder better manage the quantity risk. For example, the bidder can guarantee winning a desired minimal quantity of each deal by bidding a high price—and being a price taker—for this minimum quantity.

With multiple deals, the dynamic auction is conducted with multiple price clocks, one for each deal. The auctioneer announces a price for each deal, and the bidder responds with the quantity desired for each deal. Given the limited importance of complements in this setting, it makes sense to use a simple implementation. After an initial switching phase where customers can bid on any deal, each deal is treated as an independent, but simultaneous, sale. This means that monotonicity of bids is enforced deal-by-deal, and each deal closes independently. Independent closing limits substitution across deals, but a simultaneous ascending auction with limited switching still gives each bidder the ability to dynamically bid for a desirable portfolio of diamonds across all deals . This provides much greater flexibility than is allowed with the static methods. Bidder budget constraints are also much better managed.

The sealed-bid method has one important drawback, which is mitigated in the dynamic auction. Bidders are forced to decide which deals to bid on before seeing how many other bidders have decided to bid on the same deal. This can result in many bidders competing for some deals and few bidders competing for others. In the dynamic auction, the initial switching phase where customers can freely switch among deals resolves the coordination problem inherent in the seal-bid method. The switching phase allows bidders to equalize competition across all deals, improving the efficiency of the auction. Both BHP Billiton and its customers benefit from the improved pricing of the dynamic auction with an initial switching phase.

6.5   What if demand curves are not downward sloping?

Some have argued that customer demand curves for diamonds are upward sloping, so that all or most customers will bid for the maximum quantity. We were suspicious that this perception of upward sloping demand curves was an artifact of the previous system in which Regular customers were getting too small a quantity at too low a price. These Regular customers were thus arguing for more quantity and providing reasons why they need more quantity in the hopes that they will get more. We suspected that as soon as customers could bid directly or the prices rose we would observe the familiar downward sloping demands. Typically, once a minimum sufficient scale is reached, dealers will have diminishing marginal value for additional quantity for the simple reason that opportunities for using the stones will be ordered from best to worst, and the dealer will exploit the best opportunities first. The solution implemented forced customers to express either flat, or downward-sloping demands. Very rarely did customers express flat demands. We infer that customers' previous willingness to pay more for higher quantity was a consequence of prices being below competitive market prices and the sales quantity being less than the quantity demanded.

6.6   Adjusting the price book

The price book is used in two ways.

First, it is used to account for quality differences in a split of a deal. For this use, only the relative price factors are relevant, such as the percentage price difference between an 8 and 9 ct stone, holding color and quality constant. It would be possible to periodically ask customers to give feedback on these relative price factors. Truthful responses should be expected, since bidder risk is reduced if the quality adjustments better reflect the bidder's true preferences. BHP Billiton could then update and potentially disclose the relative price factors based on the feedback. (These can also be estimated based on deal composition and prices bid.)

Second, the price book is used for setting reserve prices in the auction. For this purpose, the absolute price level is relevant. The price book can be adjusted with each cycle in a similar manner as it was adjusted using the previous sales process. However, greater weight can be placed on the recent auction outcomes.

6.7   Maintaining customer diversity and avoiding collusion

Collusion, both tacit and explicit, is sometimes a problem in situations where the same buyers compete on a repeated basis, as is true here. Explicit collusion is a concern given that the vast majority of customers are located within 1 km of the center of the diamond district in Antwerp and are likely to be personally known to each other.

One means of guarding against collusion is making sure there is a sufficient number of customers and that the customer pool is sufficiently diverse. Ideally customers would come from several geographic locations, several ethnic groups, and several company structures. The upper limit on a customer's share in the deal (e.g., 40%) is the primary method of assuring that there is a sufficient number and diversity of customers and manageable credit risk. If these instruments prove inadequate, then targeted marketing is used to attract desirable buyers.

The rough diamond industry is conducive to diversity with many ethnicities and nationalities present in the diamond district. There are many customers based in Belgium, India, Israel, the Netherlands, and South Africa. The high number of customers, many of whom are fierce competitors in the polished market, makes it less likely that a collusive cartel will develop successfully. Historically, there has been little need for a customer cartel. De Beers provided a below-market price to all of its

customers. Rather than pushing De Beers further below market prices by forming a cartel, customers pushed to expand quantity with De Beers perhaps by lobbying and gaming reports to De Beers. Some families have several companies, one per brother. This outcome may be an artifact of De Beers allocating quantity by customer qualifications.

The reserve price is an essential instrument to mitigate collusion. It does this by limiting the maximum gain from engaging in collusive activity. At the same time, it mitigates the harm from successful collusion.

The Code of Conduct clearly spells out that any discussions about bidding strategy with other bidders is forbidden and is illegal under competition laws. Such discussions would be grounds for exclusion from the current and possibly any future auctions.

A final instrument to mitigate collusion is the information policy—what bidder's learn during the bidding process. Limiting information often enhances competition in repeated auctions. Thus, rather than reporting prices and winning shares at the end of each auction, it is better to only report prices. Similarly, in the clock implementation it is better to only report prices and aggregate demand at the end of the round, rather than all the individual bids.

Physical facilities for securely viewing the parcels limited how much the customer pool could be expanded which might have limited the effectiveness of recruiting to expand the customer pool and to target specific kinds of buyers. Noting that viewing rooms were a scarce resource led to tighter management of the resource to allow more customers to use it. Low volume customers were asked to view during off-peak times. This allowed an expanded customer base to make collusion more difficult and for BHP Billiton to benefit from more robust competition and a broader range of private values.

The auctions provide valuable information for customer selection and the allocation of scarce viewing time. Customers are ranked based on the value they add. Poor performers are removed from the customer pool.

6.8   Auctioning large stones

Large stones of 7 carats or more, "Specials", are auctioned separately in independent auctions several times a year. The Specials auctions attract attention of the market participants even though these stones represent less than 10% of the revenue from the Ekati mine.

 Depending on the size and quality, the stones are auctioned as individual stones or bundled with similar stones. A simultaneous ascending-clock auction is used in the Specials auctions. Price discovery is particularly important for these stones, given their rarity and value. The ascending-clock process also lets the bidders better manage portfolio needs and budget constraints. Finally, by using the same approach as the Term auction, the customers were able to become familiar with the auction format for the Term auction.

Five Specials auctions have been run to date with extremely high demand at the start of each auction due to the low starting prices below the reserve prices. In the first auction, demand averaged more than 10 customers at the starting prices for each of 40 parcels.

To enhance customers' ability to value large stones, a recent innovation is to include a DVD that includes a 3D image of the stone and the data required by cut-optimization software. This allows the customer to see all imperfections and determine the optimal cut, and thereby get an excellent estimate of the polished outcome.

6.9   Further bundling or unbundling

For continuity a similar deal and price point structure from the previous sales process is used today. Some changes were made in the deal structure in order to have critical mass for the Spot and Term. The bundling of about 4,000 price points into about 19 Spot and 16 Term deals is an effective structure in the auction market.

"Illusion" is sometimes mentioned as a reason for bundling. It is apparently effective because larger bundles tend to go unsold less often because reserve pricing errors sometimes offset. Furthermore, if two parcels are auctioned separately and one does not sell, it is common for the unsold parcel to subsequently sell at a reduced price in a negotiated sale following the tender. This is a rational market response. The fact that the parcel failed to sell in a tender is bad news about its value (those that inspected it were unwilling to bid more than the reserve price). Subsequent customers should value the parcel at less. This, however, does not mean that bundling the two parcels would raise seller revenue. Whether to bundle depends more on the heterogeneity of bidder demands. Less bundling can provide more transparency and better matching in situations of sufficient demand heterogeneity. Viewing times and costs may also be reduced with effective bundling.

Bundling does simplify the auction and reduce transaction costs. Technology can also lower some transactions costs. For example, the fourth Specials auction had over 50 parcels. Customers interested in 25 of them might have to type quickly to enter all of their bids during the auction round. Labor saving devices such as proxy bidding and displaying only those parcels a customer is still bidding on allow the auction to still be run in a few hours.

Our suspicion is that less bundling, not more, may be better.

7   Spot market composition

The Regular, Elite, and Tender/Window were combined into one Auction sale. A uniform-price auction was used in the initial years, although clock auctions are being used for more stones over time and are contemplated as an approach for all stones in future years. Both approaches are commonly used, are well understood, and are well-suited to the setting.

Among the sealed-bid methods we prefer the uniform-price auction to the pay-as-bid auction and this was selected. Uniform pricing provides better incentives to bid true values, especially given the competitive market structure we anticipate. It also is easier for the customer to guarantee a desired minimum quantity. With this approach, customers get the benefits of quantity certainty on whatever quantity they wish to be price takers. In addition, customers like the fact that they do not overpay the market clearing price on any quantity won. Uniform pricing has greater price variation across cycles than pay-as-bid pricing. However, given the fairly liquid market for rough stones and the use of a reserve price, we do not expect this greater price variation to be a problem.

The best alternative to the uniform-price auction is the ascending-clock auction. The clock auction is similar to the uniform-price auction, but has several additional benefits. In particular, the multiple-round approach of a clock auction provides valuable price discovery, and it allows bidders to better manage budget constraints and quantity risk. It is especially desirable when bidders care about the particular portfolio of stones won.

The clock auction is slightly more difficult to implement and entails slightly higher participation costs for the bidders. It takes about three hours to conduct the clock auction with 50 price clocks for a Specials Auction. In the Spot market, the additional benefits of the clock auction may not exceed these extra costs when the market is less volatile. Work is ongoing to develop auction technology to allow a

faster ascending auction for the Spot market. A shorter clock auction will have somewhat less price and assignment discovery than the longer Specials auction, but more than the uniform-price auction. The clock auction does allow bidders to raise their bid if they are losing, so market feedback is immediate. This is important, especially when diamond prices are more volatile.

Both recommended approaches build on the previous approach, through the use of deals to bundle many related price points. This greatly facilitated the transition to the auction market.

A challenge for the clock auction was that it may be perceived by some customers as too dramatic a change. This was one of the reasons to begin with the uniform-price auction for the Spot market, and then transition to a clock auction as needed, once customers are comfortable with the auction process. Switching from the uniform-price to the ascending-clock is a natural and modest step.

The critical assumption for the auction approach is that a bidder can examine a representative sample of the deal and bid on that, knowing that what it receives may be somewhat different than the sample it inspected, with a price adjustment based on the price book. This works fine provided the viewing parcels are representative of the deal, and care is taken in making sure that the parcels created for winning bidders are also representative of the viewed parcel to the extent possible. Thus far, the approach has worked well. The assumption seems modest, when compared to the De Beers approach of being presented with a take-it-or-leave-it offer for a parcel of stones selected by De Beers.

The big difference between the auction methods and the previous sales process is that with the auction approach the customers compete directly for quantity and pay the market price for any quantity won. With the previous process, competition for quantity is much less direct and much more complex. The auction approach does a much better job of putting the diamonds in the hands of those customers best able to use them. In addition, the pricing under the auction approach better reflects competitive market prices. The improved assignment and pricing of diamonds under the auction approach appears to translate into higher sales revenues for BHP Billiton and allows the best customers to expand.

Risk of collusion is another issue to address in the auction market. Our conclusion was that a well designed and implemented auction market would be less susceptible to collusion than the previous system, especially the reliance on the price book. Thus far, our conclusion appears sound. There have not been any instances of collusion observed.

8 A long-term market to foster regularity of supply

Customers value regularity of supply. An important question is how one can create value by enhancing supply regularity.

After considering durations from 6 to 36 months, BHP Billiton decided to hold an auction to sell 18-month Term supply contracts. The contracts are for a particular percent of each deal in each of the fifteen cycles during the 18 months. An ascending-clock auction was used, with a different clock (price) for 16 deals, one for each deal. Bidders bid the quantity (number of splits) they desire for each of the deals, given the price, which is a percentage of the Spot price. The auction is started at a discount to the Spot price, such as 5%. Each clock price is raised until supply and demand balance. As described earlier, a uniform-price auction is used in the Spot market to assign and price the residual portion of each deal that is not sold in the Term auction.

The Term auction was open to an expanded group of potential customers, rather than restricted to a set of regular customers.

For each customer, there is an upper limit on quantity in each deal, of two or three splits representing 42-60% of available long-term supply for that deal or 25-35% of total supply for that deal. Deals that allow a higher percentage to be won by one bidder are deals that represent a smaller absolute amount of money. The number of splits for each deal is closely correlated to the expected total sales price for all splits in the deal.

The motivation for using an ascending-clock format for the Term auction is that it allows the customers over the course of the auction to build a desirable portfolio of deal quantities, given the observed premiums over Spot prices. The auction was conducted in four hours (an hour longer than expected, since prices exceeded expectations). An alternative design would use the uniform-price auction; however, we believe that the extra price and assignment discovery of the ascending clock was helpful to bidders in the Term auction given that each Term auction allocated much more value than each Spot or Specials auction. Extra price and assignment discovery were especially important in early auctions, where there was more uncertainty.

To illustrate how a customer builds a portfolio of quantities that makes sense given the prices for each deal, imagine there are three deals (A, B, and C) up for auction. Suppose A and B are substitutes for the bidder, and that C complements the A or B purchase. Then during the clock auction, the bidder can start out bidding for both A and B, and then reduce its purchase of the one with the larger premium. Similarly, as the premium for C increases, the bidder can reduce its demand for C as well as A and B.

Under this approach, the mine's output, excluding the portion set aside for the Northwest Territories and the large Specials stones, is sold in two markets: a Term market, which offers regular supply at a premium above Spot and a Spot market. The division between these two markets depends on the customers' preferences for regular supply and the requirement to preserve critical mass for Spot sales. A substantial premium for regular supply was observed. For each deal, as high an amount as possible was selected that would still preserve critical mass for the Spot market price to be meaningful. 50-65% of supply of each deal was provided to the long-term market except for three deals with insufficient supply which went solely to the Spot market.

Since the Term contracts may be for a premium over the Spot price, it was essential that the bidders have confidence in the Spot market. This requires transparency in conducting the Spot market. The Spot market was run for a period of time, until the customers gained confidence that it was producing reasonable prices.

The Term contracts are similar to the Elite channel, except the contract is must-take—the customer does not have the option of rejecting its share of the deal unless the Spot market fails to produce a price. Each bidder knows that it is committed to purchasing its particular percent of the deal at the market-clearing price premium.

It is natural to ask why a customer would bid a premium over the Spot price. Can't the customer achieve supply regularity in the Spot market simply by bidding high for its desired quantity? Then it gets the quantity, but does not pay a premium above Spot. The answer is subtle and has to do with commitment. The Term supply contract commits the bidder to winning a particular fraction of the deal in each cycle, regardless of the Spot price. This commitment puts the customer in a desirable position relative to others competing for supply, and thereby reduces quantity risk. However, the advantage is limited, and indeed may be negative if customers care more about price risk than quantity risk. Our sense, however, is that quantity risk is the primary concern, and therefore, we expected and saw a clearing price premium for most of the deals. The premium was on the order of 3-5%. This is a large premium which is about the same as BHP Billiton's estimate of its customer profit margin.

Even if the premium falls in the future, BHP Billiton should not be discouraged if the price premium is zero or negative for many deals. A zero price premium would result if a sufficient number of customers believed that they could successfully purchase stones in the Spot market. In this case, BHP Billiton has successfully reduced its own quantity risk by selling a portion of its supply forward. We expect the premium to trend downward as customers become more expert on bidding in the Spot and Term markets.

Forward contracts often have the advantage of improving the performance of the Spot market by reducing incentives for the exercise of Spot market power. However, the Term contracts discussed here, since they base the price on the Spot price, do less on this score. Large winners of Term contracts still have an incentive to reduce demands in the Spot market, since the Spot price is determining the price paid for the entire quantity, not just the Spot quantity. Nonetheless, the contracts do limit how much a customer can reduce its demands. Hence, market power and collusion are somewhat improved by the Term contracts, but both market power and collusion remain important problems to watch. BHP Billiton guarded against this by expanding the number of customers allowed to bid in the Spot to encourage competition even if no Term customers bid in the Spot auction.

The Term market provides supply regularity that is valuable not just to customers but to BHP Billiton. Customers with long-term commitments have a greater incentive to make investments that enhance the value of the mine's output. BHP Billiton shares in the value created from these investments. In turn, BHP can conduct long-term planning on the value of increasing mine production which the customers will benefit from.

9 Transition

As anticipated, the Regular customers reacted negatively to change, since they enjoyed purchasing at prices that were somewhat below competitive market prices. This reaction took the form of lobbying BHP Billiton to criticize the plan, talking down the plan—even predicting disaster. Many of these criticisms focused on a reduction in loyalty, price transparency reducing intermediary profit, and the effectiveness of auctions at achieving better prices driving customers out of business.

Nonetheless, new customers and some Regular customers were strongly in favor of the new approach. These customers were able to obtain more supply without lobbying or setting up new entities. Large expanding customers especially liked the ascending auction to allow tailoring of a supply portfolio during the auction as prices evolve.

Due to the fragmented nature of rough-diamond demand, it is likely in BHP Billiton's long-term interest to encourage industry consolidation. It will become more difficult for customers to profit from pricing inefficiency which will put pressure on customers to innovate or merge. This will be especially true if De Beers member countries turn to market methods to allocate a portion of their production amongst their customers.

BHP Billiton's careful attention to customer needs allowed it to maintain good relationships with its Regular customers through the transition. Vigorous discussion with customers synthesized improvements in contract terms that helped both BHP Billiton and its customers. Some of these contract terms only became viable in the presence of a competitive market. For example, BHP Billiton provided a six-month contract with two six-month options to continue buying at the same price. This would have been a difficult option to price if BHP Billiton had to do so unilaterally. A competitive auction allows the market price to be discovered so that BHP Billiton need not be overly cautious in offering a favorable contract to customers.

Favorable contract terms help customers reframe their relationship with BHP Billiton. Customers no longer benefit from pursuing zero-sum bargaining about contract terms. Competition raises the market price to reflect the value of contract changes. Customers can focus on lobbying only for changes that create value such as minimizing overall risk and figuring out which party is best suited to shoulder it.

To gradually get customers comfortable with the approach, the first Term auction in September 2008 was limited to a handful of deals. This is a full-scale test of the approach for the deals offered, since the entire deal is sold under the new approach. The gradual approach also allows some fine-tuning based on experience. To avoid "gaming of the experiment," the subset of deals utilizing the new approach represented a significant fraction of the total value of mine production.

One issue requiring ongoing study is how best to set reserve prices to manage collusion, revenue risk, and other factors. This has been especially important during the global financial crisis.

The key to a successful transition was careful development and then education of customers. For Regular customers, moving from the classic De Beers approach, in which both the price and the assignment are set by the seller, required some gearing up. One way to ease the transition was to start with the uniform-price auction for the Spot market, and then switch to the clock auction only if needed and after the customers have gained experience with the auction approach. BHP Billiton instituted a comprehensive education campaign involving both large and small-group training sessions and practice auctions.

For the Term market, we found that customers prefer and BHP Billiton benefits from the use of the ascending-clock auction. Given the higher stakes of the Term market, we found that greater price and assignment discovery was well worth the slightly higher implementation cost.

In making these recommendations, we assumed that the demand-side for rough stones was competitive. We have found no evidence to the contrary. This assumption is supported by the fact that BHP Billiton's initial steps away from the De Beer's model—the Elite, Tender, and Window sales—were not met with customer revolt. A competitive demand side means that BHP Billiton cannot be harmed by the boycott or exit of an individual customer. There are many potential manufacturers and resellers that desire to become BHP Billiton Customers.

10 Results

BHP Billiton successfully ran Spot sales every cycle for over a year and held two or three ascending auctions per year for large stones. BHP Billiton had a surprisingly good result for its transition Term auction in September 2008 for approximately 20% of annual mine output with prices 5% higher than expected.

In February 2009, BHP Billiton held a Term auction for 60% of Ekati mine production with the balance to be auctioned in the Spot market. The auction concluded successfully. All 81 splits in 16 deals were sold. The price was an average of 103% of the Spot market clearing price (SMCP) for terms of 6, 12 or 18 months at the option of the winner. The auction result was consistent with competitive bidding. The 103% average price exceeded expectations of BHP Billiton. The quantity result was also impressive, especially in the middle of a massive financial crisis. All splits of all deals selling is counter to an industry trend of lower volume sold and indicates a growing market share for BHP Billiton.

BHP Billiton Term auction, February 2009

Round	Average start price (percent of SMCP)	Deals sold / deals	Aggregate demand* / supply (splits)
1	95.00%	0 / 16	222 / 81
2	95.56%	0 / 16	142 / 81
3	96.06%	0 / 16	137 / 81
4**	97.06%	0 / 16	232 / 81
5	98.06%	0 / 16	213 / 81
6	98.94%	2 / 16	196 / 81
7	99.94%	2 / 16	167 / 81
8	101.25%	6 / 16	131 / 81
9	102.26%	7 / 16	103 / 81
10	102.77%	12 / 16	90 / 81
11	103.02%	14 / 16	84 / 81
Final	103.03%	16 / 16	81 / 81

* Aggregate demand at the beginning of the round except for round 1 where it is at the end of the round.
** This reflects the final opportunity for customers to increase Demand.

Actual aggregate demand going into Round 4 was 232—nearly three times supply which is consistent with a competitive auction. The 3% price premium above Spot prices also suggests a competitive auction.

On the day after the auction, 21 February 2009, the headline of a business story in the *New York Times* was "Diamond Sales, and Prices, Plunge." This was a tough time for an auction, but the approach did well despite the challenges. Fortunately, the ascending clock auction is excellent at establishing—or re-establishing—confidence in a difficult market.

Many factors contributed to the success. The value proposition of a Term contract pegged to the Spot price is clearly excellent with the auction exceeding price expectations. The addition of options for the customers to extend a minimum six-month term to twelve or eighteen months improved the value of the contract to the customers further to offset the dismal market sentiment. Better utilization of client rooms allowed twice as many customers as in the previous Term auction—several times the number of Regular customers under the prior approach. Customers were also targeted based on Spot bidding profiles to enhance competition across all deals.

An excellent value proposition, targeting of new customers who have interest in specific deals, high visibility to potential customers, a simple auction design with a good implementation, excellent training, documentation, and outreach to prevent technical and conceptual issues getting in the way of bidding all helped facilitate this superb outcome.

11 Conclusion

In thinking about a new sales process, it is helpful to reflect on why De Beers established the rather peculiar institution where customers are given a sack of stones and told the price. De Beers needed this tight control of both price and assignment as it was developing the market for diamonds in the first hundred years of the industry. The approach was made possible by the near monopoly position of De Beers.

Today, the diamond market is well established. Large but non-dominant sellers like BHP Billiton do not benefit from the De Beers approach. Rather BHP Billiton benefits from getting the stones into the hands of those that value them the most. For this to happen, a more market-responsive sales method was needed.

We worked with BHP Billiton to develop and implement auction methods to replace several of the previous sales channels for the Ekati diamonds. The auction approach does a better job of assigning and pricing the mine's output. Customers compete directly in simple auctions. In this way, the diamonds are allocated to the customers with the highest values, and the prices paid reflect current market conditions. The auctions allow each customer to express preferences for various quantities and types of stones, and find the value-maximizing assignments. Prices are competitively determined, with much less reliance on the price book. The extra value created from the better assignment of the stones results in higher sales revenues for BHP Billiton.

Spot auctions are held ten times per year and currently use a uniform-price format.

To foster supply regularity, the approach includes an auction for Term supply. A customer desiring a supply commitment of up to 18 months, bids a percentage differential to the Spot price for the quantity of each deal it desires. An ascending-clock auction allows each customer to build a portfolio of supply commitments across deals that best meets its needs, and pays the market-clearing price premium. By satisfying demands for supply regularity, BHP Billiton further enhances the revenues it achieves from its Ekati mine resulting in a premium of 3-5% above the Spot market price in two successive Term market sales.

Large stones also are sold two or three times per year in Specials auctions. An ascending-clock auction is used to better facilitate the discovery of market prices, and allow bidders to manage portfolio and budget constraints.

The auction approach rewards BHP Billiton's best customers and keeps them focused on their business and being competitive.

A key benefit of the approach is transparent pricing consistent with market fundamentals. The approach has proven robust to the global financial crisis, which has rocked the diamond industry. Both prices and quantities have exceeded expectations.