Beating Competition and Maximizing Expected Value in B. C.'s Stumpage Market

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Abstract: Though primarily focused on maximizing expected value, this article covers three other important considerations in developing a bidding strategy: Bidder behavior, how much to invest in bid development and avoiding the winners curse. The presentation uses data covering the whole Province of British Columbia for the period of April 2003 until May 2005. Bidder behavior reports on the movement of bidders into and out of the stumpage market, how many times they have bid and how many times they have won. The data, including reserve price (upset rate), bid (bonus), stumpage, volume, individual bidders, sales date, among other things, are used to estimate the cumulative probability of a specific bid winning an auction, develop a bid function that maximizes expected value and analyze the value of investing in error reduction for bid preparation. Value of investment in error reduction is determined by using a Decision Theory approach to estimate the value of moving toward perfect information. An approach to avoid the winner's curse is presented.

Keywords: Stumpage, Auctions, expected value of perfect information, Expected Value of Sample information, Expected Value of Improved information, winners curse, bidding strategy

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Introduction

The forestry sector in British Columbia is undergoing a fundamental change in policy as it moves to letting market forces set stumpage prices. As of May 2005 approximately 30% of the Province's AAC is priced using the Market Pricing System (MPS). The MPS has two parts. BS Timber Sales auctions stumpage on an open market and then market evidence is used to estimate the market price of stumpage not sold on the open market. All of the Coastal Region of B.C. is under the MPS and B.C. Timber Sales is operating in the Interior. Comparative value pricing, (CVP) still in use for most long term tenure and lease holders in the Interior, is being phased out (B. Howard (BC MOF, personnel communication, 2005)).

Auctions are a popular way to sell a wide variety of things and have been used to sell timber for many years. They are expedient for the land owner because they are not required to know the value buyers place on the timber. Bidders decide what to bid. The timber owner just has to publicize the auction, format and rules. B.C. Timber Sales uses a first price sealed bid auction with a reserve price (called upset rate in B.C.). The highest qualified bidder wins. The payoff (P) for the bidder is the difference between the revenue derived from log sales and the cost of getting the logs to market including stumpage price (S). The winning bid (B, called "bonus bid" in B.C.) plus the reserve price is stumpage for that sale. Timber auctions have a common value, where each bidder estimates what they think the timber is worth, and they understand that their estimate is not exact. Estimates of timber volume by species and grade, the cost of logging and transportation and the future price for logs all have error associated with them. Bidders appraise the value of stumpage (V) using a derived residual value approach (figure 1).

V = [(Log price by species and grade x Log volume by species and grade) – (harvest and transportation cost) – (legal, overhead and miscellaneous costs) – (bid preparation cost) + error]/ Total Volume – Upset rate

or

V = Payoff + bonus bid (see figure 1)

With BC Timber Sales, the upset rate and bonus bids units are $\$/m^3$, and the valuation (V) for a stand of timber must be reduced to $\$/m^3$. In this discussion, V is what the timber is worth to the buyer, including upset rate but not bonus bid. The error in V comes from error in estimating timber volume by species and grades and estimating cost of processing stumpage to the market of highest value. Timber volume error is estimated when summarizing cruise data, but must be converted into a $\$/m^3$ units to be consistent with the bidding process. The white line, in figure 1, represents the bid amount. It is in the seller's interest to move it up and the buyer's interest to move it down. Its' level is the decision which the bidder must make. The expected value for each bidder is their estimate of V; however all they really know is that the true value is probably greater than V about ½ the time and less the other ½ of the time (figure 2).

The width of the distribution (amount of error in the estimate) depends on how much the bidder is willing to invest in the appraisal. At one end of the bid preparation spectrum, the bidder could guess the value. This type of estimate is inexpensive, quick and depending on experience of the bidder can be "in the ball park". At the other end of the spectrum, the bidder could do a 100% cruise of the timber sale using highly qualified and experienced foresters, who grade every log in every tree, who assess the terrain, access and other pertinent cost factors and who evaluate the data using sophisticated time tested engineering cost models. This is expensive; it does decrease error and narrow the distribution (figure 2). But what is a narrower distribution worth?

The payoff for the bidder is the true value of the timber minus whatever they pay for the timber if their bid is the highest, or minus bid preparation cost if not (figure 1).

The payoff (P) function is: P = V – B: If Bid (B) > all other bids and the upset rate
Stumpage (S) = B + upset rate
Otherwise P = cost of bid preparation.
S = highest bid + upset rate

Now, the game begins. If there is only one bidder and they estimate V greater than the upset rate then they bid the upset rate (+ 0.01 if required to beat the upset rate). However, in B.C. you cannot be sure who or how many bidders are planning to bid on a specific sale. To win, a bidder must increase their bid to beat the competition. Auction theory and subsequent research have established that for most auction designs, winning bid increases with the number of bidders (Stark and Rothkopf (1979), Brannman and et al.(1987) and Engelbrecht-Wiggans (1980)). In B.C. this is true[2]. More bidders or even the threat of more bidders produce pressure to increase your bid. If you want to win you have to bid more than all other competitors.

In the past 2 years BC has had at least 833 separate bidders place 2979 separate bids on 762 timber sales. Another 121 sales did not receive a single bid. Of the 833 bidders, 417 have not won a single contract. As shown in figure 3 only a few bidders have won multiple auctions and the majority of winners have won only once. Figure 4, displays the number of times bidders have placed bids. As can be seen the majority have placed only one bid. A few timber buyers are very active, with one at 31 bids.

Auction research has also established another important outcome, charmingly called the “Winners Curse” (Wilson (1992) and Matthews (1984)). The curse is placing a bid (B+upset ratge > True V) so that payoff (P) for winning is negative. No one would ever do this knowingly. So why does the Winner’s Curse happen? Look back at figure 2. If true value is out on the left hand side of the V distribution (estimate was too high), leading to a bid higher then the true V. On average about ½ the bidders will appraise (V) too high, the other ½ too low. The winning bidder typically is the one who estimates (V) too high and is more likely to bid too much. Ignorance of the winners curse results in people going out of business. Knowledge of the winner’s curse produces pressure to decrease bid amount.

We can assume that both the winner’s curse and not winning will force some buyers out of the game, but over the past two years new buyers have been coming into the market at a regular (but slightly decreasing) rate (figure 5). There is no way of knowing how many leave the market, but the total number of bidders is not showing any (statistical) trend over time, which leads to the inference that bidders are moving in and out of the market on a regular basis.

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A bidding strategy is how to win without being cursed. Bidding lower makes it less likely to win, but reduces the odds of overpaying if you do win. The greater the number of bidders the more likely the winners curse will occur, so you must be more cautious, and on the other hand, the greater the number of bidders the less likely you will win for any given bid. Calculating the optimal bid is complicated even in simple situations, and as foresters know just the appraisal of standing timber is not simple. Bidding your estimated valuation (V) is usually not a good idea. It guarantees your payoff will be negative about half of the time, but you will win contracts (until you go out of business). Bidding less than your estimated valuation reduces the probability that you win, but means you'll have better odds of earning a positive payoff if you do win. The solution to this tradeoff is a bidding strategy.

B.C. Timber Sales is interested in maximizing the expected revenue from each and every auction. This is the reasons they are using a sealed bid first price auction, restrict information on who and how many have bid, seriously penalize any bidders found to be in collusion and establish a reserve price (upset rate) below which they will not sell the timber. Since timber has an intrinsic value to the Province it would be irresponsible to sell it for less than this value. But a significant element of value to the Provincial Government is a stable supply of timber. The result is a reserve price of 70% of the estimated market value. The 70% is arbitrary, but not unreasonable, and is used as policy in many USDA Forest Service timber auctions (Huebschmann, and others, 2004). A reserve price is more important in auctions with few bidders. It offsets the lack of competition among bidders. In auctions with several bidders, it supplies information on what the seller thinks it is worth (Paarsch, 1997).

It is tacitly assumed that bidders are interested in maximizing expected revenue from each and every auction, but not all bidders behave in the same way. Sometimes, it is useful to categorize bidders by how they deal with risk. Some bidders are risk averse and some are risk takers. There are two types of risk: loosing and over bidding as pictured in figure 2. Risk averse bidders prefer less uncertainty and want to increase their chances of winning (ignore overbidding for now). For them winning is another objective along with maximizing expected value. Risk averse bidders typically place higher bids than risk neutral bidders. Higher bids raise the probability of winning, but reduce the payoff from winning. Up to a point, risk averse bidders care more about increasing the probability of winning than the lost payoff from winning. Risk takers on the other hand will bid low, gambling for the big payoff. Risk attitude is not constant. At different times the same bidder can be risk averse or risk taking.

A bidder's attitude toward risk can change in relation to business and financial conditions. If a bidder is short of work and needs to keep his company working they will be more averse to loosing and bid more. A bidder with plenty of work in the near run can afford to gamble a little and will bid less.

Toward an Optimal Bidding Strategy in British Columbia

Upon public notice of a timber auction, there are a series of three major decisions that must be made in the development of a bid.

> *The **first decision** is whether or not to place a bid. The **second decision** is how much time, effort and money to invest in developing a bid. The **third decision** is what to bid.*

Each of these major decisions has lesser (but important) choices built in, such as: What is the objective? What is our attitude for risk? Who are our likely competitors?

To answer the question "what to bid?", data on all B.C. auction results published on the Ministry of Forests' web site will be used. A reasonable objective for timber buyers is to maximize expected payoff (Bullard, 1985). Expected payoff acknowledges that sometimes you win and some times you lose, but over many sales the strategy will maximize payoff.

Maximum expected payoff is:

$$\underset{B}{Max}\ E(P) = (V(B_C) - B)Prob(B > \text{All other bids}) - B_C \quad [1]$$

Where E(P)is expected payoff as a function of bid B.

$V(B_C)$is the DRV of the timber (without B_C included) but with reserve price deducted. V is a function of B_C in that the more you spend on appraisal the better your estimate of V.
B is the bid amount.
Prob(…) is the probability that bid B is greater than all other bids.
B_C is the cost of preparing Bid. You always pay this cost.
$\underset{B}{Max}$ is the maximum over all bids.

In order to estimate Prob(B > All other bids) the BC Timber Sales' auction results are used. This discussion is for B.C. as a whole, which is instructive and useful. However, readers should be aware that specific application of the following analysis would be more appropriate when conducted for your business area, based on what you have estimated V to be and your likely competitors.

Stumpage equals upset rate plus bonus bid. A relationship between stumpage and upset rate is evident in the data as graphed in figure 6. Upset rate truncates the distribution. The (pink) truncation line (figure 6) is where stumpage = upset. The regression line and truncation line are in effect parallel (no significant difference between the slope 1.07 and 1). This observation will be useful. A graph of the residuals of the equation (in figure 6) is shown in figure 7. Note the truncation of bid residuals by the upset rate, starting at 9.8 above zero it increases by $7 for every $100. There is one significant residual pattern, other than a clustering of upset prices in the $25 to $45 range. This is that the residual distribution is **not** normally distributed around zero. The mean of the residuals is zero, but the truncation has changed the shape of the distribution and a central assumption when using regression is that the residuals are normally distributed. This means that the error statistics developed using linear regression are not appropriate.

There is an alternative to estimate Prob(B > all other bids). Go back to the observation of parallel regression and truncation lines in figure 6. The amounts over the truncation line, by definition, are the winning bids. A graph of the upset rate versus bonus bid looks virtually indistinguishable from figure 7, only it starts at zero and goes up from there. The distribution of bonus bids is in figure 8. This is obviously not a normal distribution.

Since the data appears to follow an exponential decay pattern, for purposes of discussion assume the data (figure 8) comes from an exponential distribution. Indeed, there is no statistical difference between the observed distribution and an exponential distribution fitted to the data (using Chi^2), but other functions may have a better fit. The exponential decay distribution is:

$Prob(B) = e^{-aB}$

Where e is the exponential function (exp)
a is the decay constant.

and the cumulative probability function is

Prob(B > all other bids) = $\int_0^B \Pr ob(x)dx = 1 - \frac{1}{\exp^{f(B)}}$

The cumulative frequency distribution of bonus bids is shown in figure 9, along with the cumulative exponential distribution fitted to the data. The distribution underestimates the data in the mid ranges from a bonus of ~ $\$5/m^3$ to $\$25/m^3$, which can be corrected with another distribution function or eliminated all together by use of numerical techniques.

Given the ability to estimate Prob(Bid > All other bids) the maximum expected value can be calculated. This is done using the equation [1], the probability function and Microsoft Excel's Solver ®. Figure 10 displays results of bids that maximize expected payoff, along with the associated probability of winning, as a function of V. As you can see, the higher the value of the stand the higher maximum expected value bonus bid, maximum expected payoff, and the probability of winning. The Maximum Expected payoff probability of winning levels off around 0.9. For example, if appraised value is $\$50/m^3$, then the bid that maximizes expected value is about $\$15/m^3$, and you could expect to win almost 80% of the time with this bid. The more valuable the stumpage the more you bid to win. And given a choice between a high value stand and a low value stand you can expect a greater return on the high value stand. (Not a major revelation.)

Remember, the probability estimates presented here are for the whole of B.C. For a specific firm's situation the probability estimates would be more accurate if based on the local business area and expected competitor data.

Value of Appraisal Information

*The **second decision** is how much time, effort and money to invest in developing a bid*

In the previous discussion, the cost associated with developing a bid is an integral part of the estimate. The investment in bid development influences what you bid (equation 1). A common complaint among bidders is, win or lose they have already invested money in developing a bid. This is expensive particularly when they do not win and recuperate the cost. Bidders must remember the idea behind maximizing expected value, you lose some of the time, win some of the time, pay for your bid estimates every time, but over the long run you come out on top of the game.

The question of how much to invest in bid preparation is relevant. In figure 2, the conceptual diagram of a bid estimate is presented. The distribution represents error in the estimate of V. It is generally understood that somebody who invests little in bid preparation will have a wider distribution than somebody who invests a lot of time and effort (e.g. money). Further, it is assumed that it is better to have less error in your estimate. In equation (1), the valuation of the stand $V(B_C)$ is a fixed amount and represents the expected value of stumpage. The bid that maximizes E(P)does not change directly with the error distribution (It does change with the mean of the distribution). Rephrasing the second decision, "How much should be invested in reducing the error of estimate?"

One way of answering this question is by analyzing the expected value of perfect information (EVPI) (Anderson et al. (2000), Kvanli et al (1986)) over a range of stumpage prices and associate error. Assume estimates of V are normally distributed with a standard deviation, σ, as diagramed in figure 11. Standard deviation (STDV) summarizes the measurement of error around the mean and assuming a normal distribution allows us to assign probability to different estimates of V. For example, in figure 11, the estimate of V is $50/m^3 with a STDV of $5/m^3. With this information probabilities can be estimated for different regions that the actual value might fall within.

If before we make a bid we had perfect information on the actual value of V, then we know what to bid to maximize expected value. Table 1 summarizes what we would bid (using equation 1) for the midpoints defined in figure 11. If we knew V was equal to 32.5$/m^3 the bid should be 11.2$/m^3.

Table 1: Bids for maximizing expected payoff, if we knew the actual value of the timber stand V. Units of bids and valuations - $/m^3

V with perfect foresight	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5
Bid for Max E(P)	11.2	12.38	13.47	14.47	15.40	16.26	17.07	17.83
Prob of V	0.0013	0.0215	0.1359	0.3413	0.3413	0.1359	0.0215	0.0013

However, we don't have perfect information, all we have are probability estimates of what might happen. Thus, if we did bid 11.2 then we would only have about 1:770 odds of that bid being correct. To analyze the value of acquiring perfect information we calculate what payoffs would occur if we bid expecting one outcome when it actually turns out to be quite different. Table 2 summarizes the payoffs for different actual values of V and different decisions on the bid. For example, if you bid 11.20 $/m^3 and it turned out that the actual value was 57.5 $/m^3 then your payoff is 31.15 $/m^3, but with a higher probability of loosing the bid. With 20/20 hindsight you know you should have bid 16.26 $/m^3 to maximize expected payoff.

Table 2: Payoff table for different bid decisions and different possible outcomes for actual value of the stand of timber. Units of bids and valuations - $\$/m^3$

Prob()	0.0013	0.0215	0.1359	0.3413	0.3413	0.1359	0.0215	0.0013	
	Number of standard deviation regions under curve from figure 11. Example based on mean 50 and standard deviation 5								
	3<	3<<2	2<<1	1<<0	0<<1	1<<2	2<<3	<<3	
Bids	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	$E(P \mid B)$
11.2	14.33	17.69	21.05	24.42	27.78	31.15	34.51	37.87	26.1
12.38	14.24	17.782	21.32	24.86	28.40	31.94	35.48	39.02	26.63
13.47	14.02	17.71	21.39	25.08	28.76	32.45	36.14	39.824	26.93
14.47	13.73	17.53	21.34	25.14	28.95	32.76	36.56	40.37	27.05
15.4	13.36	17.27	21.18	25.09	29.00	32.91	36.82	40.73	27.05
16.26	12.97	16.97	20.96	24.96	28.96	32.96	36.95	40.95	26.96
17.07	12.56	16.63	20.70	24.77	28.85	32.92	36.99	41.06	26.81
17.83	12.14	16.27	20.41	24.55	28.68	32.82	36.96	41.09	26.62

The last column in table 2 is the expected payoff given the bid decision in the first column. This number is the sum of payoffs times the probabilities. Note that the Max E(P) is the average of the two rows for bids of 14.47 and 15.40, and with smaller and smaller probability intervals the two middle bid rows will approach Max E(P). With perfect foresight we would bid to achieve the greatest payoff in each of the respective columns. If we knew it was going to be worth 67.50 $\$/m^3$, we would bid 17.83$\$/m^3$. Table 3 summarizes what we would do if we had perfect information about what the stand was worth. The last column in table 3 is the expected value if we could get perfect information. It is calculated as the sum of the Payoff times Prob rows.

Table 3: Expected value with perfect information. (EV with PI)

Actual value	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	EVwith PI
Bid	11.2	12.38	13.47	14.47	15.4	16.26	17.07	17.83	
Payoff	14.33	17.78	21.39	25.14	29.00	32.96	36.99	41.09	27.11
Prob	0.0013	0.0215	0.1359	0.3413	0.3413	0.1359	0.0215	0.0013	

This now can be reduced down to the expected value of perfect information (EVPI). EVPI is the difference between the expected value with perfect information (table 3) and the maximum expected value with the original information (table 2): \$27.11- \$27.05 = 0.06 $\$/m^3$. This 0.06 $\$/m^3$ is what we would expect to gain if we could improve information from V=50$\$/m^3$ and STDV = 5$\$/m^3$ to knowing the actual value of V with STDV = 0 (perfect information).

The above example was for a single value of V and associated error estimate. Expanding the analysis presented above to different values of V and standard deviations results in data graphed in figure 12. The results in figure 12 are logical, and the numbers have value. First, the more the current standard deviation the more you can afford to pay for improving the estimate. You will never be able to recoup the full value of perfect information, since there will always be error, however you can move to a lower level of error and gain the difference. For example if your preliminary estimate of V = 50$\$/m^3$ has a STDV of 20$\$/m^3$ the expected value of sample information that would give you a STDV of 10$/m^3 is 1.2$/m^3 – 0.28$/m^3 = 0.92$/m^3. If you could pay less than this to achieve the lower STDV then it would be to your benefit (over the long run) to do so. The question of how much error reduction can be achieved for every dollar invested in bid preparation, though important, is not answered here. Second, the lower the initial estimate of V the more you can potentially gain from investing in error reduction. At lower estimates for V, maximum expected value bid levels are lower along with the probability of winning but probability of winning changes more rapidly at lower V levels (refer back to Figure 9). Making a mistake at a low V level reduces your chance of winning much more (thus your maximum expected payoff) than at a higher initial estimate of V. The end result is the lower the initial estimate of V the more valuable it is to reduce your error in estimating V. When blown up for a large volume timber sale these amounts can be significant.

The results in figure 10 and 12 are general, in relation to the estimated cumulative probability distribution in figure 9. Again, these probability estimates would be more accurate in practice once refined for specific business areas and expected competitors.

Avoiding the Winners Curse

In practice not bidding too much is a simple procedure and is based on what you know about the stand including the error of estimate of V, but it also contains implications for how much risk (of overpayment) you are willing to accept. Referring back to equation (1) the value of V that you use is the expected value of the sale. Following an objective to maximize expected value you will bid the amount that maximizes expected value as long as Prob(B > True V) is at an acceptable level of risk. Prob(B> True V) is the probability of a negative return and can be estimated using information readily available from previous analysis, plus the standard normal distribution Z statistic. First, calculate the number of standard deviations B is from V.

Number of STDVs = NSTDV = $\frac{V-B}{STDV}$

Then, look up in a Standard Normal distribution Z table (most spreadsheet and database programs have this as a built in function) the probability of being NSTDV away from the mean (if a one tailed distribution table you will have to add 0.5). This is the risk of not over bidding. If you accept this level of risk you can make this bid. For example let V = 40 $/m^3 with STDV = 10 $/m^3. The bid which maximizes E(P)= 12.93 $/m^3 using equation (1).

NSTDV = (40-12.93)/10 = 2.707. Looking this up in a Z table, Prob(12.93 > True V) = (1 - 0.9972) = 0.0028.

This level of risk (about 1 out of 360) maybe acceptable for most people, but for purposes of example what if the desired level of risk was 0.001 (1 out of 1000). What would you bid now? Working backward from what was done above, if Prob(B > True V) = 0.001, looking 0.001 up in a z table gives 3.1 STDV away from mean. Then solve for bid amount: NSTDV = 3.1 = (40-B)/10. The risk constrained bid B = 9 $/m^3 gives you a risk of 0.001 of overbidding, or a 0.999 probability of making a profit, if you won. Figure 13 summarizes the over bid probabilities associated with following the maximum expected value bid. It is clearly better to have a more precise estimate of V.

When pushing your bid to avoid risk of losing you increase the risk of overbidding. Using this method you can check your risk exposure to overbidding. Avoiding the winners curse comes down to making a new decision on how much of a risk of over bidding you will accept and not bidding over that amount.

Summary

The discussion covers three important considerations in developing a bidding strategy: Maximizing expected payoff, determining how much to invest in bid development and avoiding the winners curse. It does not go into the important first decision of whether or not to bid in the first place. This is determined by the bidders business and financial situation and specific sales information published in the MOF sales notices. The presentation uses data covering the whole province for the years of 2003 until May 2005. Potential bidders interested in using these methods should develop estimates based on data from their specific business area and expected competitors.

This information is not new to large companies. Applications of decision theory are in common use. This information will add the smaller timber buyers in B.C., but it is the nature of information to change behavior. Once this information becomes commonly used the probability distribution will change and a new dynamic will result. It is up to the timber buyer to continue to adapt to the competition and refine the methodology contained herein.

Acknowledgements

Many people and groups contributed to the work contained in this paper. The US/Canada Fulbright Program provided the funding along with intellectual stimulation to make this possible. The North Carolina Agricultural Research Service and North Carolina State University provided funding and logistical support for my time in Vancouver Canada. I appreciate their support and thank them for freedom of thought. The Faculty of Masters of Public Policy Program at Simon Fraser University made available operational support, resources, ideas, experience and friendship all of which made my visit to B.C. a positive experience. Professor John Nelson at UBC made arrangements for me to come to Vancouver without which this would not have happened. Bill Howard of the Revenue Branch of the B.C. Ministry of Forests provided thoughtful guidance, comments and contacts though out the province. The Council of Forest Industry's Peter Aflick provided much insight and information into the workings of the forestry sector in B.C. Many other individuals, too many to list in a few short pages, contributed with both hospitality and information during field tours, interviews and discussions. Thanks y'all.

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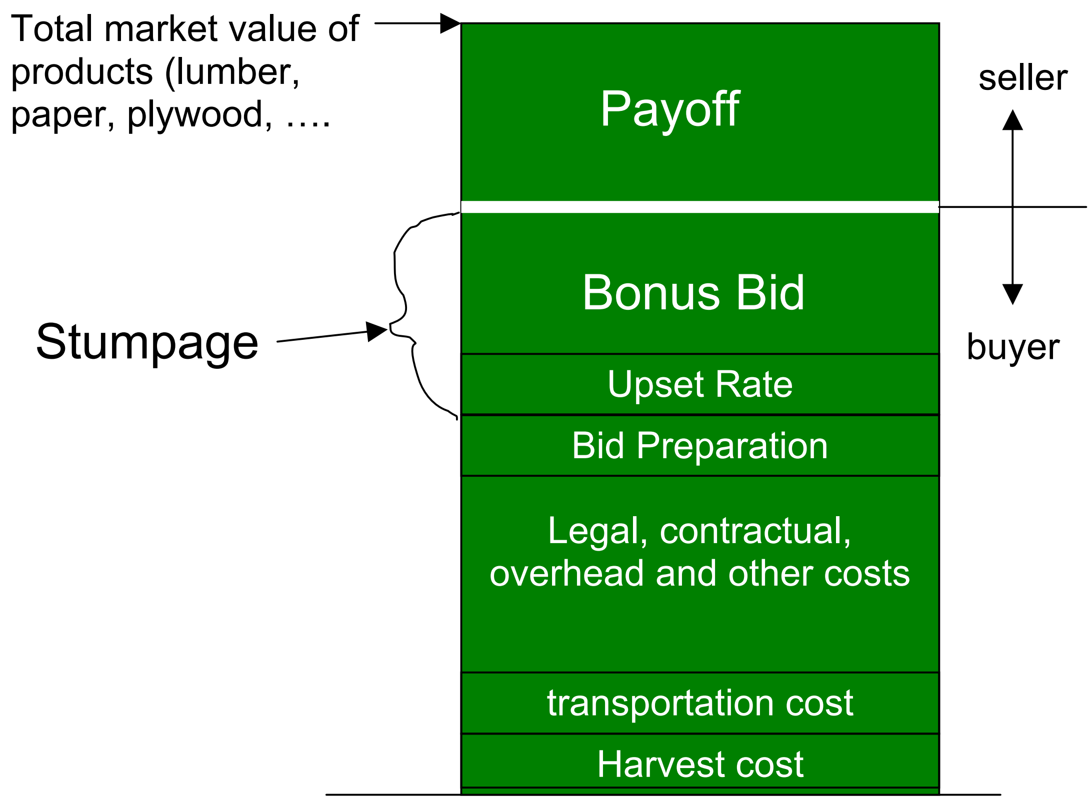

Figure 1: Derived residual value estimate of stand value (V), Stumpage price (S) and payoff (P).

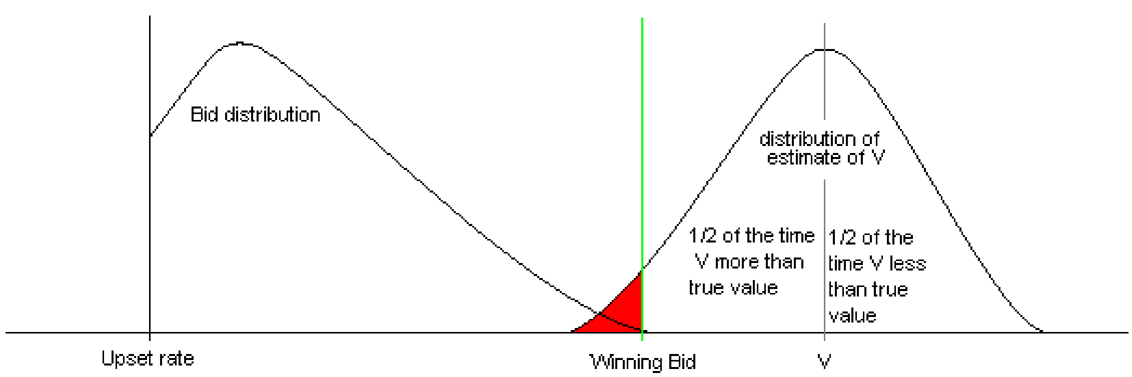

Figure 2: Major sources of risk for an individual bidder. The bid must be enough to beat all competitors and yet not over bid the true value of the timber.

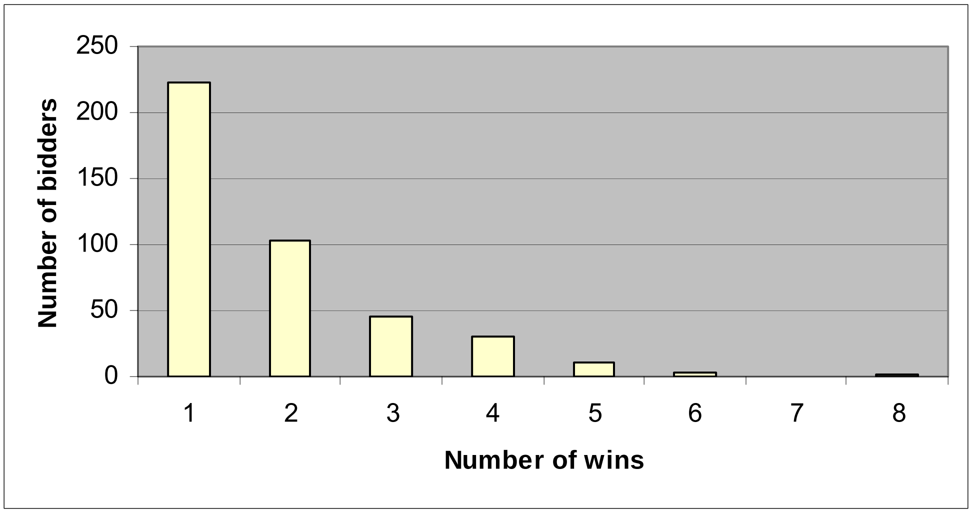

Figure 3: Distribution of number of times a bidder has won. There has been only one bidder who won 8 times, 223 bidders who have won once, and 417 who have never won.

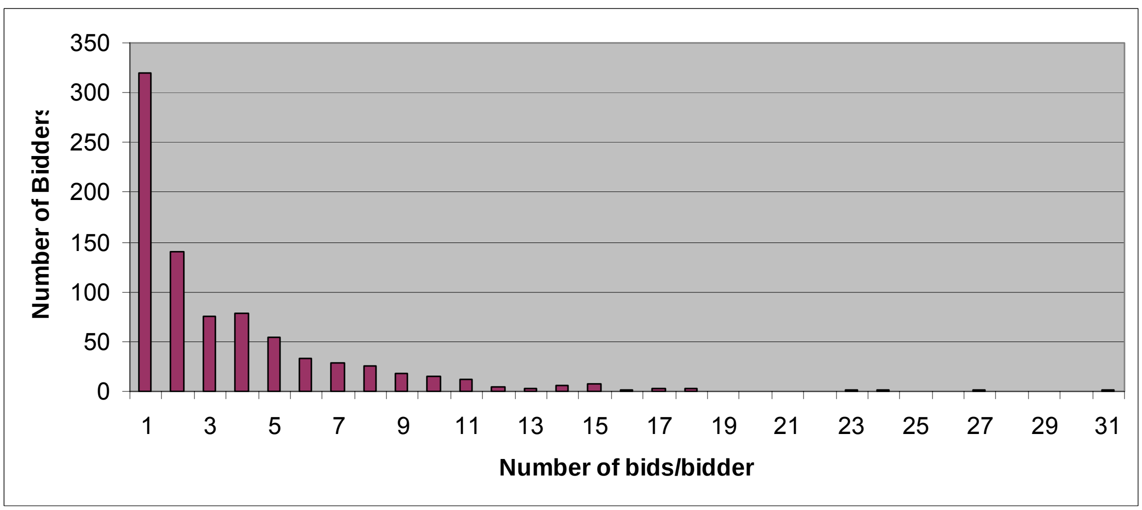

Figure 4: Distribution of the number of bids submitted for each of the 833 bidders. There is one bidder at 23, 24, 27 and 31 bids.

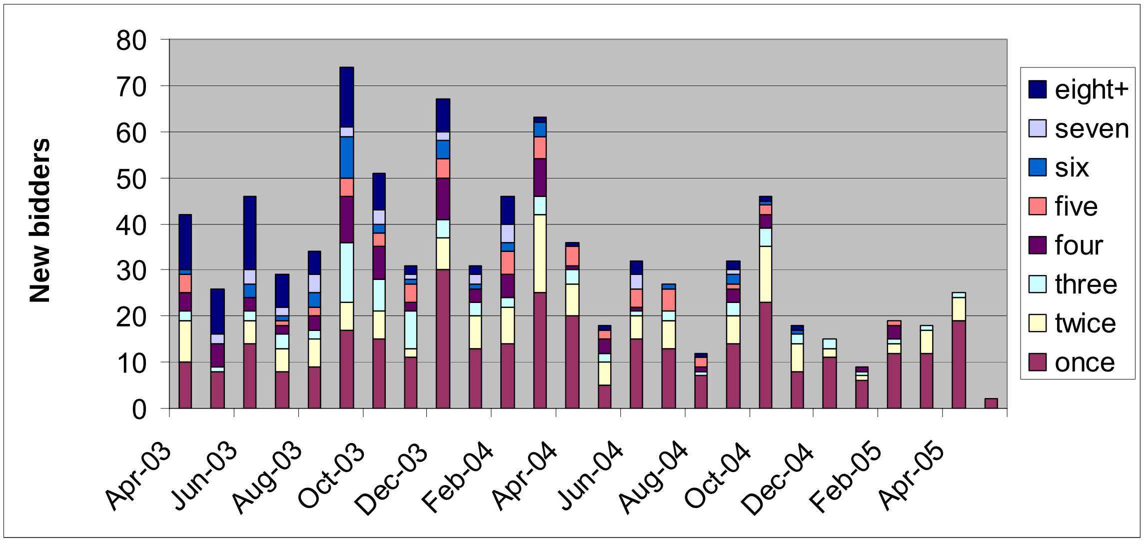

Figure 5: The number of new (first time) bidders each 30 day period. Broken down by how many times they will bid. As we get closer to the present bidders have less opportunity to have repeat bids. Number of once only bidders shows no trend. The number of first times bidders has been declining over time. (Downward slope is significant at the alpha = 0.01 level.)

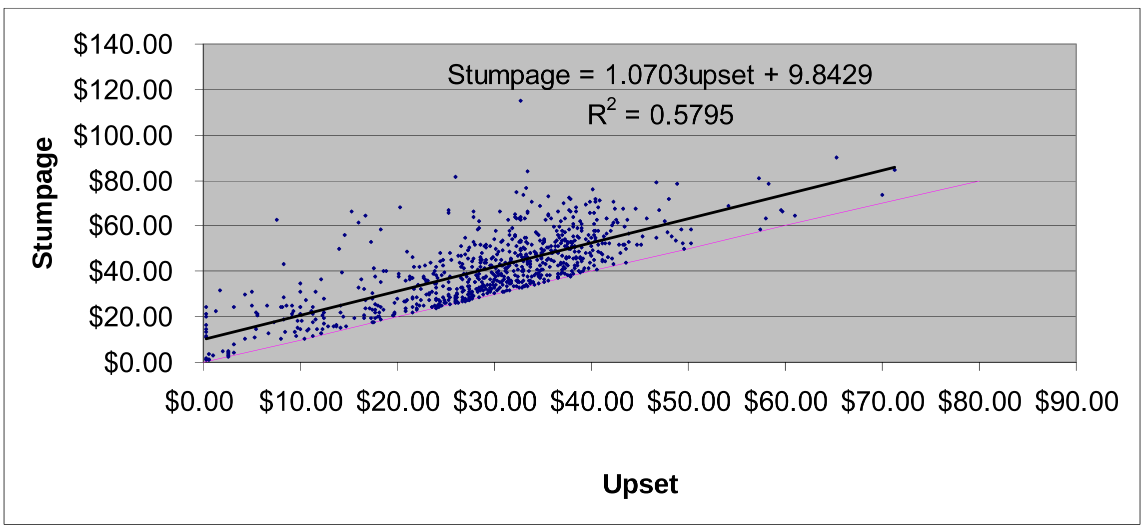

Figure 6: British Columbia stumpage (winning bid + upset) price in relation to Upset (reserve) price.

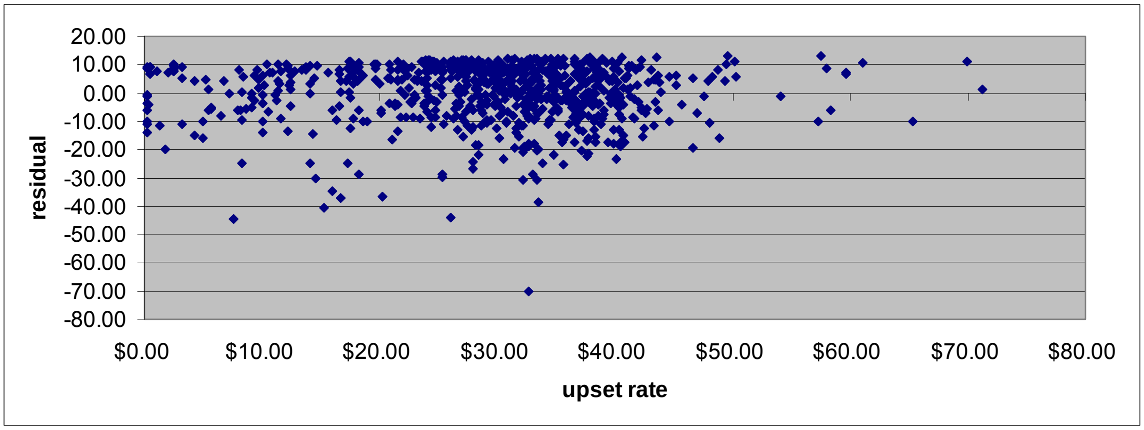

Figure 7: Residuals from the equations relating stumpage value to upset rate.

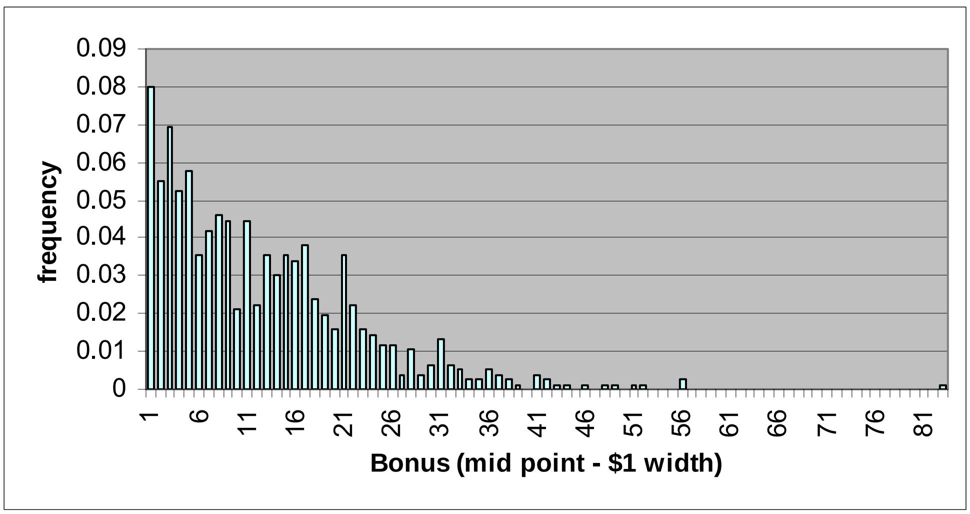

Figure 8: Frequency distribution of bonus bids. On the Bonus axis the first category (1) goes from 0 to 0.99, each subsequent category is $\$1/M^3$ wide. The mean is $\$11.88/M^3$. There is one bid at $\$82.50/M^3$.

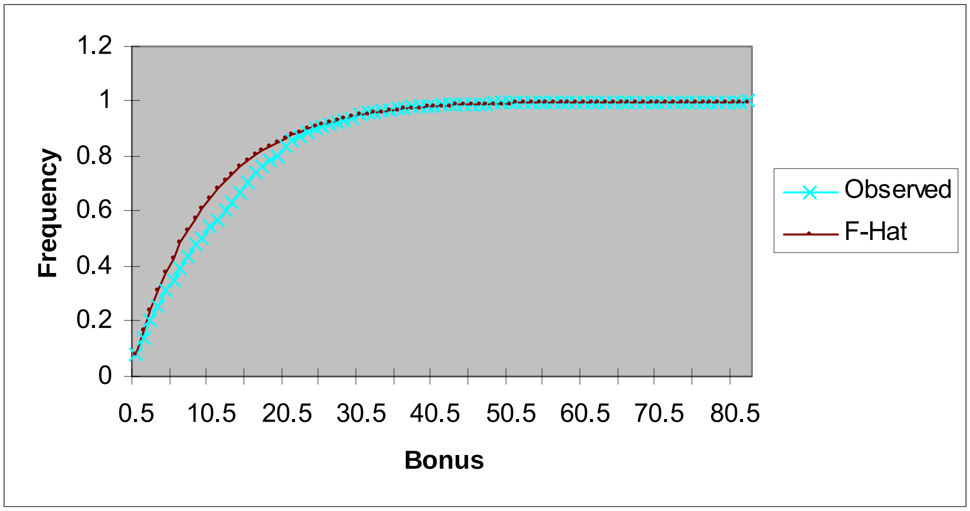

Figure 9: Cumulative frequency distribution and estimated probability distribution of bonus bids in British Columbia. F-Hat is the estimated probability based on the fitted distribution. No statistical difference between curves using $Chi^2(0.005,81)$. The actual equation is not reproduced for proprietary reasons, but graph is from actual equation.

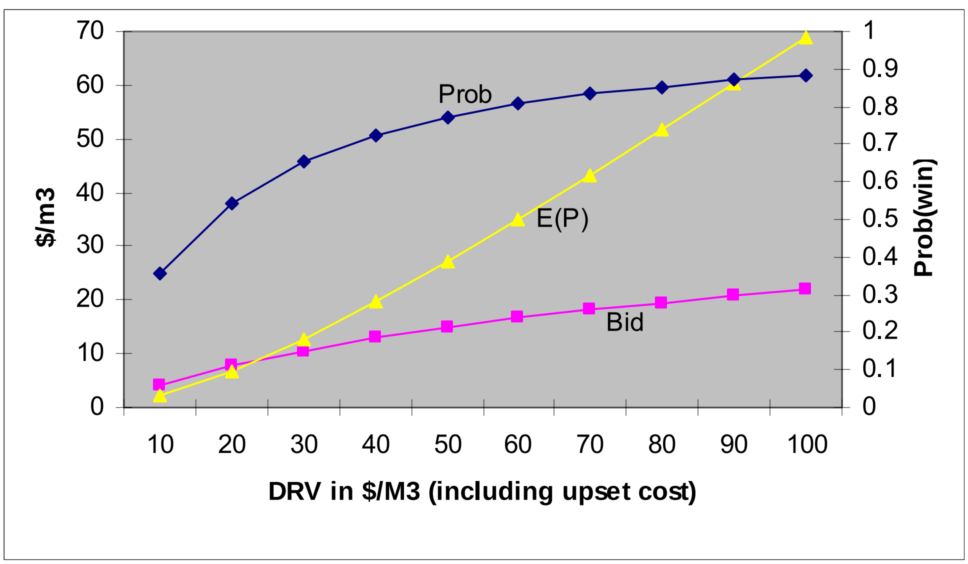

Figure 10: Maximum expected payoff, E(P), bonus bid and probability of winning in relation to the derived residual value (V). Probability axis is on the right. The Bid and E(P)axis is on the left.

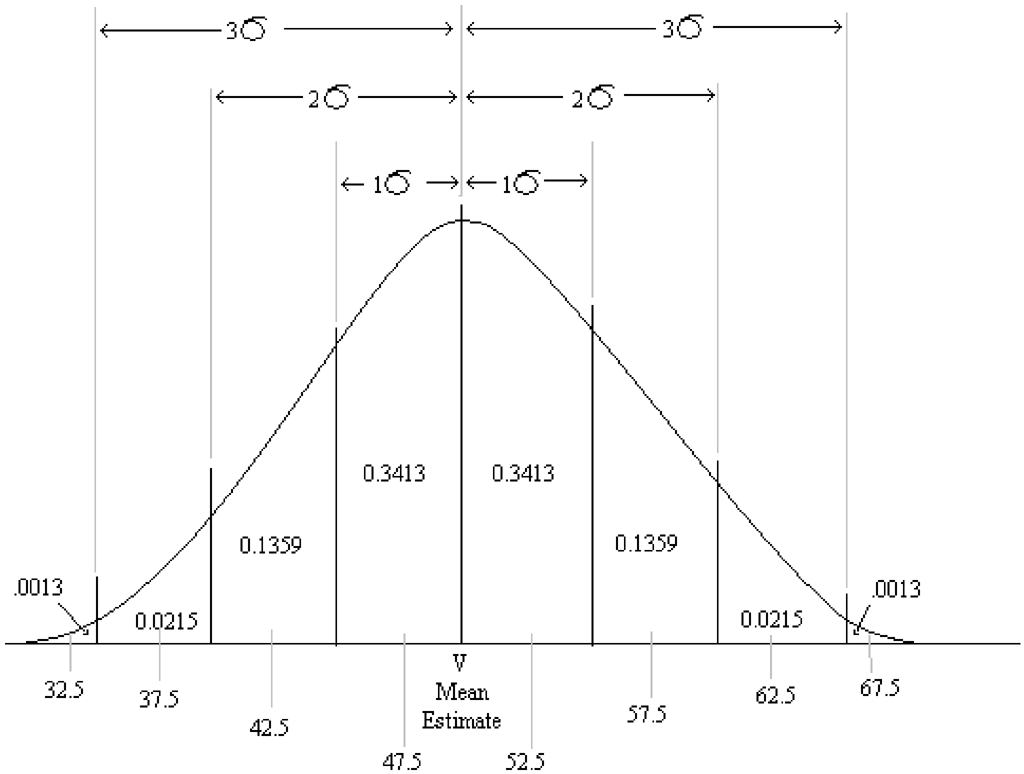

Figure 11: Probability of different regions under a normal distribution with mean V = $\$50/m^3$ and standard deviation σ = $\$5/m^3$. Numbers along the bottom axis are V midpoints for each region. At mean V = 50 the bid that maximize E(P)is 14.94, however the probability of actual V = 50 is 0.

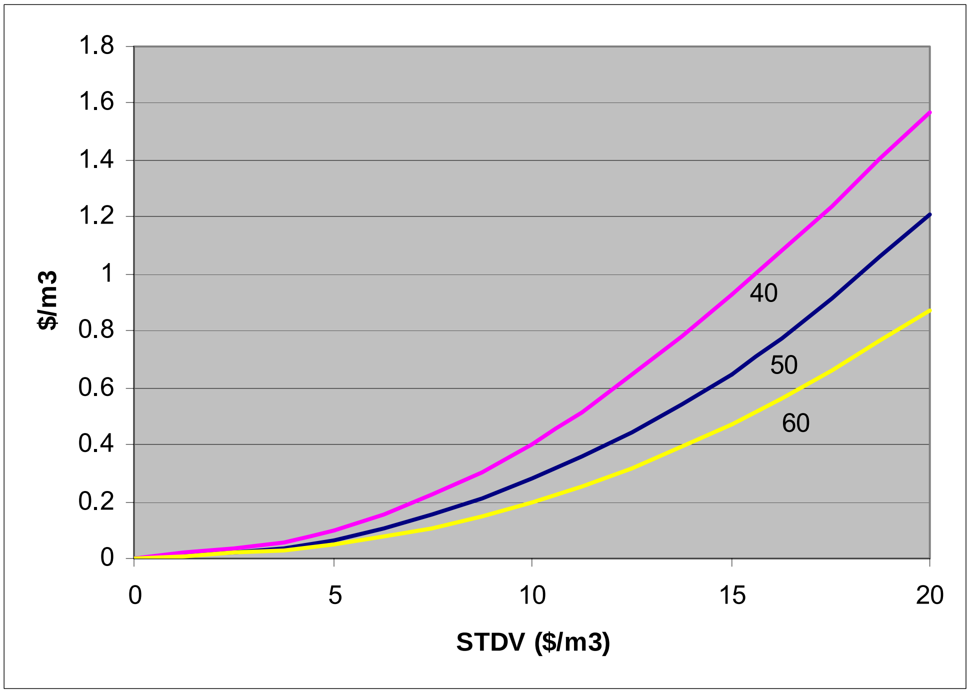

Figure 12: Value of perfect information as a function of standard deviation for three different estimates of V (40, 50 and 60).

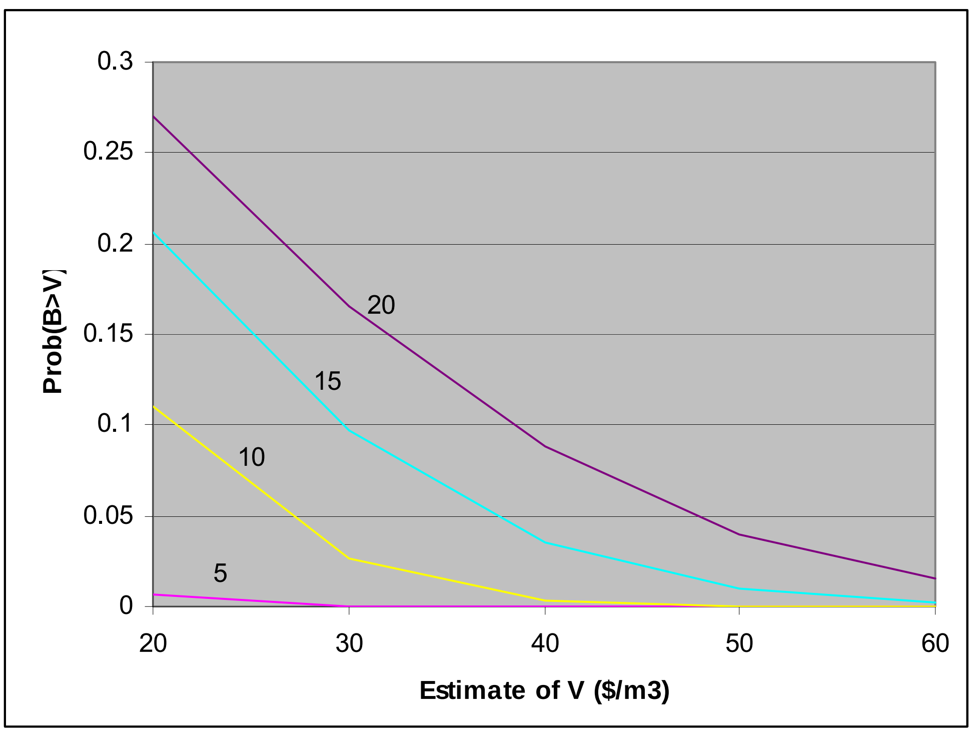

Figure 13: Probability of overbidding the true value of stumpage given the estimated value of stumpage and the standard deviation, when using the bid which maximizes expected payoff.