Auction-Based Timber Pricing and Complementary Market Reforms in British Columbia

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SUMMARY

British Columbia is proposing substantial market reforms to improve its pricing of timber. We analyze the important issues that these reforms raise. A key element of the reforms is using the outcome of timber auctions to price timber for non-auctioned long-term tenures. Using market transactions to price timber on long-term tenures has the advantage of setting market-based prices for all of B.C.'s timber, while retaining the benefits of long-term tenures. The market-based approach enables efficient cutting of timber, efficient investment in developing timber lands, and minimizes the impact of government decisions on timber pricing.

British Columbia is considering not just one reform, but a set of complementary reforms. In our analysis we consider the main elements of the reform package together. A representative portion of timber is sold at auction. The remaining timber is allocated through long-term tenure arrangements—that is, the arrangements that regulate a company's ability to harvest timber, as well as its obligations for forest management, on B.C. public land over an extended timeframe. The price of standing timber under long-term tenures will be based on the price of auctioned timber, less the tenure obligation adjustments, which compensate companies for forest management activities. The pricing system for standing timber under long-term tenures will be the equation-based Transactional Evidence Pricing System. Logs may be freely sold between tenure-holders and mills. Market forces will decide if mills should remain in operation, and the correct employment levels at those mills. Constraints and subsidies that interfere with these market forces will be eliminated. Together, the market reforms eliminate trade distortions, allow for efficient entry and exit, and promote efficient specialization. Companies see the correct price signals and have the flexibility to respond with efficient operating and investment decisions.

A critical issue is how much volume should be auctioned. Certainly, an advantage of the long-term tenures is greater reliance on private-industry decisions with respect to when and what to harvest; rather than letting government's command-and-control decisions dominate the market. However, it is essential that the auction volume be large enough to ensure that the proposed pricing system functions correctly. In particular, we assess what volume is needed to ensure that: (1) the estimated prices have sufficient statistical precision, (2) the market is sufficiently thick, and (3) problems of strategic bidding are avoided. These three factors—statistical precision, market thickness, and absence of strategic bidding—place a limit on the minimum auction volume that can achieve reliable market-based prices for all timber.

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We find that most gains in statistical precision are obtained with moderate auction volume, on the order of 15 percent, and that the gains in precision from auctioning more than 15 percent diminish rapidly..

In terms of market thickness, we observe that in the current small business program, where only 6.5% of volume is auctioned, there is already reasonable competition at auctions, and competition is likely to increase once restrictions on who may bid are removed. Given that sealed-bid auctions are proposed, in which bidders worry about the risk of losing the auction when it would have been profitable to win, we anticipate that if the auctioned volume is at least 13% (the scope of the current small business program, taken as a whole), there will be sufficient participation to induce bidders to bid aggressively. We do not expect that the number of competitors at each auction will increase dramatically as the volume sold at auction increases beyond 13%.

Finally, we establish that the most important factor in deterring strategic bidding at auctions is the choice of model specification, not the overall volume. Even with the current level of volume in the small business program (6.5%), one auction has a negligible impact on the estimation of the pricing equation, because the pricing model is estimated using auctions conducted over several years throughout the Interior or Coast, respectively. We show that with slight modifications to the Ministry's specification, even if mills and loggers in a given locality managed to reduce auction prices substantially over the course of three years, this would have a small impact on the prices the local licensees would pay for stumpage.

Although our analysis indicates that problems with market thickness and strategic manipulation are unlikely, we make specific recommendations about how the Ministry should monitor competitiveness at auctions, and we propose actions that the Ministry can take to address problems that might arise.

Thus, we believe that potential problems with statistical precision, market thickness, and strategic bidding will be addressed by auctioning volumes of about 15 percent, and we see little reason to believe that there will be substantial improvement in the functioning of the markets at greater levels of volume.

There are some important costs to be considered in increasing the volume sold at auction beyond this level. The total volume harvested is the single most important factor in determining British Columbia exports and hence British Columbia's influence on world prices. Thus, it is critically important that market forces determine this volume, rather than the Ministry of Forests. If British Columbia sold 100 percent of the volume through auctions, and the government does not respond quickly enough to market signals, it would flood the auction market in a downturn. Auctioning "too much" volume would lead to depressed auction prices and excessive exports, which in turn would further soften world lumber prices. In contrast, if the volume auctioned is smaller, then the tenure holders can choose to harvest less from their long-term tenures in downturns. In this regard, the tenure holders would make efficient cutting decisions that are similar to private land-holders.

We strongly favor a system where market forces determine the total volume harvested. This objective is achieved by the proposed system—minimum annual cut restrictions are removed and long-term tenure-holders pay market prices for timber but retain decision-making for the timing of harvests for a substantial portion of the volume.

1 INTRODUCTION

We have been asked by the British Columbia Ministry of Forests to analyze the important issues in using the outcome of timber auctions to price timber for non-auctioned long-term tenures. The basic approach is to auction an appropriate share of British Columbia's timber rights, and then use the auction prices to determine stumpage fees for non-auctioned timber held under long-term tenures. Our qualification of the proper approach is that the pricing mechanism should accurately predict the market value of non-auctioned timber. Thus, the best auctioned-based approach is the one that best forecasts market prices.

The idea of using market transactions to price non-market transactions is not new. This is a common form of pricing within large organizations. For example, General Motors, as well as other companies, set prices for internal transactions using market prices, in a process known as tapered integration. Indeed, the most common way for pricing non-market transactions is to determine the price from comparable market sales. This is the approach proposed for the British Columbia timber industry.

One example of using an auction of a portion of assets to price the non-auctioned portion is seen in electricity restructuring in the United States. For example, in Texas, the former utilities are required to auction off 15 percent of their generating capacity. The auction prices are then used to determine the value of the remaining 85 percent of capacity, which is then used to calculate stranded costs.

In most markets that involve substantial capital investment, the vast majority of transactions are long term. Only a small fraction of transactions occur in the spot market. The long-term contracts encourage capital investment by reducing uncertainty about whether critical inputs will be available or whether outputs will receive a price sufficient to warrant the investment. The long-term tenures in British Columbia provide mill operators a predictable source of supply, as well as encourage efficient investment in the timber lands under long-term tenure. The spot market, where currently 13 percent of the timber volume is traded,[2] gives mills an opportunity to make short-term adjustments to inputs and outputs in response to current prices.

Wholesale electricity markets around the world provide another example. These markets are characterized by large capital investment and reliance on long-term contracts. Typically, only 5 percent to 20 percent of the energy volume is traded in the daily spot market. The remaining 80 percent to 95 percent is traded in long-term contracts. Both buyers and sellers benefit from locking in the vast majority of their volume well in advance of the spot market.

Thus, although markets where only a fraction of trade takes place in the spot market are common, they typically function best when trading is not subject to many restrictions. Thus, a proposal to use auction-based timber pricing should not be considered in isolation. Instead, it should be considered in conjunction with complementary, market-based reforms to British Columbia's regulatory setting.

We begin by providing an overview of the auction-based pricing system and complementary market reforms, highlighting the ways in which the reforms interact. We then consider a number of specific issues in greater depth.

2 A PACKAGE OF COMPLEMENTARY REFORMS

British Columbia is considering not just one reform, but a set of reforms. Thus, the importance of considering the key elements of the reform package together cannot be underestimated.

[2] Approximately one-half of this volume is sold at auction, the remainder through a competitive bid proposal process in which non-price criteria are also considered.

This section provides a general overview of the components of our preferred approach to reforms. Although the set of proposed reforms has many components, we will group some of them together to simplify the discussion of the relationship among them. Subsequent sections flesh out a number of specific issues in greater detail.

1. **Some timber will be sold at auction.**
    a. This volume will form the basis for a statistical model (the equation-based "Transactional Evidence" pricing system) that can predict what prices would have been if other tracts had been sold at auction under similar competitive conditions.
    b. The volume needs to be representative enough, and the number of sales sufficient, to provide predictions within reasonable bounds. The volume and composition of sales needs to reflect current market conditions. The auction agency should seek to mimic licensee behavior—putting slightly less on the market in downtimes and auctioning a species mix that reflects the current market demand.
    c. Upset prices[3] will be used to ensure that at least a minimum, fair price of auctioned timber is achieved. Typically, the upset price will be set at 30 percent below the estimated value of the timber stand, but it will not fall below the Ministry of Forest's costs.
    d. The term of the sale will be sufficiently short, and the possibilities for extensions sufficiently limited so that bid prices reflect short-term estimates of the value of the timber.

2. **In British Columbia, a substantial volume of timber has been allocated through long-term tenure arrangements. For this timber, the decision of how much volume to cut in a particular year will be made by Tenure holders rather than the Crown, up to a maximum allowable cut.**

    a. Forest Licenses and Tree Farm Licenses will be made transferable, subject only to the requirements that transfers do not raise competitive concerns, and that obligations under long-term tenures are met. There will be no transfer tax or employment guarantees.
    b. There will be no minimum cut levels or requirements to remove and process timber or logs, but there will be maximum cut restrictions that apply over a five-year period.
    c. The volume allocated in this way should be large enough so that, in any foreseeable market downturn, firms would be able to reduce their harvest enough to accommodate the downturn, while taking as given the volume that the Crown lets at auction.

3. **The price of standing timber under long-term tenures will be based on the price of standing timber sold at auction, less the tenure obligation adjustments.**

    a. The system for pricing will be transparent and will minimize the possibilities for distortion.
    b. The tenure obligation adjustment system will be transparent and will approximate the prices the Crown would have to pay on the open market for the services provided by firms.
    c. Timber will not be sold at a price below the Ministry of Forests' cost.
    d. Lots will be designed to include timber utilizing common infrastructure, so that "cross-subsidization" across timber stands is eliminated.

[3] An "upset price" is what auction theorists call a reserve price or a minimum acceptable bid. Only bids at or above the upset price are accepted.

4. **The pricing system for standing timber under long-term tenures will be the equation-based Transactional Evidence Pricing System (TEPS).**

    a. The equation-based approach accurately forecasts the fair market value for non-auctioned timber. In particular, regression analysis using the equation-based approach shows that when a sufficient volume is auctioned, prediction is accurate. The equation-based approach can also be made sufficiently resistant to attempted collusion.
    b. This system provides a specific formula for pricing timber, according to the characteristics of the tract. This system does not leave discretion to the Crown to reduce prices.
    c. If, for the tract characteristics included in the model, the distribution of characteristics is similar for the tracts sold at auction and those sold under long-term tenures, then the average price of timber sold at auction will be the same as the average price of timber sold under long-term tenures, less the tenure obligation adjustment.

5. **Logs may be freely sold between tenure-holders and mills, and open-market log transactions will be encouraged..**

    a. There will be no restrictions on the trade of timber harvested under long-term tenures, nor will there be restrictions on the minimum volume of timber to be harvested in company-owned mills.
    b. The Crown will encourage the development of an active and transparent log market.

6. **Market forces will decide if mills should remain in operation, and the correct employment levels at those mills.**

    a. Provisions to reduce a company's allowable cut following downtime will be eliminated.
    b. Provisions where government assistance is given to help mills remain operating when they would otherwise not be economically viable will be eliminated.

Consider some of the ways in which these reforms are interrelated. Clearly, in order to implement Transactional Evidence pricing systems, it is necessary that sufficient timber be sold at auction to form a basis for the pricing system (1). The equation-based system (4) provides a well-specified and easy-to-understand formula, thus ensuring transparency and eliminating the possibility for gaming. Further, the equation-based system guarantees that, so long as the tracts sold at auction are representative in terms of the observable characteristics included in the pricing equation, average prices are the same in auction and non-auction markets.

In addition, once firms have the responsibility for selecting how much to cut in a given year (2), it becomes important for them to be able to forecast accurately the prices they will pay for standing timber. The equation-based system allows them to forecast these prices several months in advance, if they can assess the characteristics of a given tract that enter into the pricing equation.

The functioning of log markets will be greatly enhanced by reforms (5), and (6). Under the existing system, log trading is limited, so it is not surprising that the log market does not function well. Reform (5) eliminates these restrictions. Even if a formal log market does not emerge, when restrictions are removed, trades should occur among individual firms. For example, suppose that mill *A* has an exceptional demand for timber. A neighboring mill, mill *B*, which is operating at closer to its optimal throughput, should be willing to sell some timber to its neighbor. If there is a formal log market, the purchases by mill *A* will drive up the price in the log market, inducing mill *B* to sell. Now, what if mill *A* and mill *B* both are short of logs, and cannot sell their products at a price greater than their average cost given their input volume?

If the shortages are severe enough, reform (6) allows mill *B* to take some downtime, and sell the logs to mill *A*, or vice versa. Similarly, in a market downturn, reform (2) prevents the log markets from becoming flooded, and reform (6) allows some mills to take downtime.

These forces all complement reforms (1) and (3). In particular, when mills experience a shortage of logs, they can choose to cut from their long-term tenure, if they are under their five-year maximum, buy on the log market, or buy at auction. Thus, prices in the log market (formal or informal) should be closely related to those at auctions. If prices at auction are temporarily low (for example, during a market downturn), tenure-holders may choose to reduce the volume they cut from long-term obligations. This highlights the important role played by reform (2): the ability of firms to slow down their cutting implies that market forces determine the total volume processed by BC, not centralized decisions by the Crown.

This logic leads to a final, important point, one that will be discussed in more detail below. If *all* Crown timber is sold at auction, then the Crown effectively determines the volume exported by BC. In a market downturn, if the Crown sticks to a pre-specified plan that does not adequately respond to market signals, then "too much" timber will be auctioned. In this scenario, with only a weak private market as a benchmark, government supply decisions are unlikely to be appropriately responsive to the market. Firms, recognizing that they will receive a low price on the output market, will reduce their demand. As a result, auction prices will fall dramatically. The B.C. exports will be "too high" relative to what the market would produce, and world prices may fall, exacerbating the pre-existing market downturn.

In contrast, if the Crown only sells a fraction of its timber at auction, then under reform (2), the total volume produced by BC in a downturn will respond to market forces. The amount auctioned will stay fixed or change in line with the market, but tenure-holders will choose to cut back on the amount of timber they harvest, delaying the harvest until better times. The importance of this factor cannot be understated: exporting too much timber during market downturns is the primary way that B.C. exports can effect the U.S. market. This market distortion can best be avoided if the Crown leaves cutting decisions to the discretion of its tenure-holders.

In summary, together, the market reforms eliminate trade distortions, allow for efficient entry and exit, and promote efficient specialization. Companies see the correct price signals and have the flexibility to respond with efficient operating and investment decisions.

3 EQUATION-BASED PRICING

An important issue is how to translate auction prices to stumpage fees. This is made difficult by the enormous variety of timber lands in British Columbia. The equation-based Transaction Evidence Pricing System (TEPS) uses an econometric model to estimate what auction prices would be on the long-term tenures using the bid data from auctioned timber. The data include all of the main determinants of auction prices. In this way, the price for a stand of non-auctioned timber is set so that it reflects the particular characteristics of the stand.

Some issues must receive attention in implementation. First, it will be important to select a sample of tracts for auction that adequately spans the range of sale characteristics present in the sales outside the auction market. Second, it will be important to exercise care in handling data from auctions where the timber is not harvested (for example, one might eliminate such sales from the dataset). Third, it will be important to carefully consider the best equation to be used, and to establish a process for evaluating changes to the equation, noting that changes should not occur to frequently. Fourth, to prevent auction manipulation, the specification should avoid the use of dummy variables for specific localities, or other variables that essentially identify small local markets. Fifth, care should be taken to consider the types of "outlier" sales that might occur, and if necessary, the equation and/or the sampling scheme can be adjusted to avoid mispricing sales with unusual characteristics. By auctioning a representative sample of stands, the possibility of outliers is minimized. One alternative is to set guidelines for "unusual" sales such that as many as possible unusual sales are sold at auction.

4 VOLUME

A critical issue is how much volume should be auctioned. Currently, 6.5 percent is auctioned under the Small Business Forest Enterprises Program (SBFEP). This can be increased to 13 percent by auctioning those SPFEP stands that are now awarded by competitive proposals, rather than a price-only auction. An increase in volume beyond 13 percent will require the auctioning of some stands that are currently held under long-term tenures. Increasing the auction volume beyond 13 percent will mean that the Ministry of Forests will have to somehow re-acquire existing long term tenure rights and will then play a larger role in the market, since it will have effective control over a larger share of the harvest.

Certainly, an advantage of the long-term tenures is greater reliance on private-industry decisions with respect to when and what to harvest; rather than letting the market be dominated by command-and-control decisions of the Ministry of Forests. Moving to a system where 100 percent of the timber is auctioned would likely increase the government's role in setting prices. In particular, the government would be determining nearly 100 percent of the supply of timber, since 94 percent of the timber is on public land. In contrast, in the U.S. where 100 percent of the timber on public lands is auctioned, the U.S. Forest Services' impact on timber prices is greatly reduced by the fact that most timber is coming from private land.[4] For example, if the U.S. Forest Service decided to auction a large quantity of a particular type of timber, the price response would be greatly muted by a reduction in the supply of this type of timber from private lands. In BC, under a 100 percent auction program, the impact on prices could not be muted by a private-sector response, since there is insufficient timber coming from private lands. The long-term tenures in BC essentially serve the same role as the private land timber in the U.S. Both serve to limit price distortions caused by government decisions with respect to when and what to harvest.

However, it is essential to ensure that the auction volume meets the minimum necessary for the effective functioning of the proposed pricing system; and to test whether 13 percent is an appropriate share. The following considerations are relevant:

- A larger volume increases the statistical precision of the estimated prices. Given the enormous variety of BC timber, the sample that is auctioned needs to reflect this diversity on all dimensions that are found to be important determinants of prices. It is important for the auctioned sample to be representative in all times, both at the top and bottom of the business cycle. If the volume is too small, there may be insufficient demand for the auctioned timber in down turns. Further, the sample size needs to be sufficiently large for the estimated prices to fall within a particular confidence interval. A suitable sample can be established from standard sampling and statistical techniques.

- A larger volume potentially mitigates problems of thin markets. Thinner markets are more volatile and more prone to market failure. A larger volume thickens the market. A thicker market has lower volatility, and lets the auction prices better reflect the true economic value of the timber. A larger volume also increases liquidity in the log market. The greater efficiency of the log market improves the timber market, since the log prices are a critical determinant of bids in the timber auctions. Market thinness is especially a problem at the bottom of the business cycle. At these times, a low volume will mean that mills likely will be

[4] In 1997, only 4 percent of the U.S. timber harvest volume was from USFS sales (source: USFS website and email). Over 90 percent of the volume comes from private land.

able to acquire all the logs they need from long-term tenures. As a result, auction prices may be unreliable.

- A larger volume potentially reduces the possibility of strategic bidding. With lower volume there is a greater risk that a licensee will have an incentive to distort the outcome of the timber auction by either reducing its demand for logs (if it is not participating in the auction directly) or reducing its bids (if it is participating in the auction). The incentive to engage in such behavior decreases as the volume is increased, since the licensee's ability to influence price is reduced. This incentive is greatly reduced if locational dummy variables are excluded from the pricing equation.

The three factors above—statistical precision, market thickness, and absence of strategic bidding—place a limit on how small the auction volume can be, while still achieving reliable market-based prices for all timber. We now address how each of these factors affects the volume of timber that must be auctioned off in order to ensure fair market prices.

4.1 Volume required for statistical precision

To determine the volume necessary to ensure accurate pricing of long-term tenure stands, we design a Monte Carlo experiment—that is, a sensitivity study of the effect that volume has on the accuracy of the regression model. Our methodology is as follows:

- We generate a random dataset that reflects the characteristics of timber stands in British Columbia, and then apply the bidding rule that was estimated in the SBFEP, making sure to induce an unexplained component of bids that was similar to that we observed in the SBFEP dataset.
- We then sample a fixed percent of the stands in the dataset 100 times. During each of the 100 iterations we estimate a regression of the explanatory variables on the bids. We then calculate statistics that describe the "fit" of the regression and the confidence intervals for the "true" regression line given our estimates.
- We repeat the above methodology, but with a higher volume, and observe the extent to which the larger sample improves the fit of the regression and reduces the confidence intervals for the regression line.

To generate a sample dataset that accurately reflects the population of timber stands in the interior forests of British Columbia we apply the means and standard deviations of those regression variables to a standard normal distribution. When the regression variable is skewed—having a large tail on the right side—we first take the natural log of that variable to center it, and then perform the statistical transformation accordingly.[5] Certain variables also tend to move with other explanatory variables in the model, a trait called "multicolinearity." Applying the appropriate multicolinearity relationships from in-sample regression to the random data allows us to generate a random dataset that accurately reflects the true data. Appendix A details the Monte Carlo simulation.

We sample (in 5 percent increments from 10 percent to 50 percent) the representative stands in our model, and then compute the R^2 for the regression, and standard errors of the forecast from the model. Thus, we can see how the "fit" of the regression, and the size of the confidence intervals, are improved by increasing the sample volume. Table 1 below contains these results.

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[5] Lognormal random variables have large right-hand side tails. Taking the natural log of a lognormal random variable results in a normally distributed random variable.

TABLE 1. RESULTS FROM 100 MONTE CARLO SIMULATIONS

Volume (%)	*Mean R^2*	*Average 95% Conf. Int. Size*	*Incremental Improvement*
10	.842	2.6874	
15	.840	2.1933	0.4941
20	.841	1.8971	0.2962
25	.841	1.6961	0.2010
30	.841	1.5474	0.1487
35	.841	1.4328	0.1146
40	.840	1.3364	0.0964
45	.840	1.2601	0.0763
50	.841	1.1964	0.0637

Appendix A, following Table A8, provides some background explanation describing these statistics.

Table 1 indicates that the statistical precision of the estimation increases with additional volume. The size of the 95 percent confidence interval around the predicted bids decreases with an increase in sample volume. Thus, the accuracy of the estimated regression line with respect to the true regression line increases with volume. The last column of Table 1 shows the incremental improvement in the precision of the estimated equation with each 5 percent increase in volume. The largest increase in the precision of the estimate occurs when we move from a sample of 10 percent to a sample of 15 percent. Here, the 95 percent confidence interval decreases by $0.494. Each further increase in volume results in a smaller improvement of our estimated regressions likely resemblance to the true stumpage equation. For example, moving from 45 to 50 percent results in an improvement of only $0.064, or about one-eighth the improvement from increasing volume from 10 to 15 percent.

In summary, we recommend that to ensure statistical precision, the auctioned volume should be at least 15 percent. Because the confidence intervals are already small at a volume of 15 percent, and because tightening of the confidence intervals is small when volume increases beyond 15 percent, statistical precision is not markedly enhanced when volume increases beyond 15 percent.

4.2 Strategic bidding and auction market thickness

There are two main ways that licensees might attempt to reduce the prices they pay for stumpage. One is to continue to produce the same level of output, but attempt to strategically manipulate auction prices so that they pay lower prices for stumpage under their licenses. The second is that the licensees might reduce their overall operations, in order to lower demand for timber and thus lower stumpage prices. (Note that large-scale cutbacks in production of this type will serve to reduce exports from British Columbia and thus raise the world price for lumber.) This section focuses on the first type of manipulation, while in Section 5 below we address the second.

The incentive of a licensee to engage in “strategic bidding” arises if a licensee can, by reducing its bids in auctions or its demand for logs from loggers who bid in auctions, affect the prices it pays for stumpage under long-term tenures. There are two forces that reduce this incentive. First, if any given bidder reduces its demand at auction then, when markets are sufficiently thick, there will be little effect on price. Because foregone profits give a disincentive for a licensee to withhold its long-run demand for logs, loggers will likely bid for the timber. In particular, loggers will anticipate that mills cannot commit to withhold their demand for logs one to two years into the future. At the time the logs become available to the mills, the auction is long past, and so is the opportunity to reduce auction prices for those logs. Thus, reducing auction prices to levels substantially below the market requires collusion among most participants in a given locality, and such widespread collusion would be difficult to accomplish (and likely would run afoul of competition laws). Second, the auction-based pricing system is based on auctions throughout the relevant region (coast or interior), and over the long-term. Thus, reducing the price in a particular auction, or even a particular locality over an extended period of time should have little effect on the prices paid for stumpage, if the auction-based pricing model is well specified.

We now evaluate the extent to which a coordinated effort to lower auction prices in a given locality (in particular, in a given district) could, even if successful, have a large impact on the prices the licensees would pay in that locality. We focus our analysis on collusion at the district level because, for the reasons just described, it will be difficult to achieve substantial price reductions (holding fixed the level of demand for logs) without the cooperation of most of the loggers and mills in a given market.

Now consider the role of volume in market thickness and strategic bidding. We observe that the current small business program attracts an average of 3.25 bidders (in a sample of auctions from 1998-2000 obtained from the Ministry), and sometimes as many as 19. This level of competition is typical of similar sealed-bid auction markets that function properly, and is therefore sufficient to ensure a competitive market. In particular, what matters to bidders is the expected level of competition. As a result, the *risk* of greater participation induces bidders to place bids closer to their true values even though the *actual* number of participants may have been smaller than expected. Once a wider range of bidders are allowed to bid, competition will increase, so long as the small bidders who currently compete in the market remain active participants. Because participation is reasonably strong at the current volume of 6.5 percent, we anticipate that increasing the volume to at least 13 percent should generate sufficient competition for market thickness. But the level of production and the amount of logging required is generally fixed in each locality. Therefore, it is unlikely that the number of loggers in the market, and hence the number of auction participants, should increase markedly as the volume sold at auction increases beyond this level.

Nonetheless, we advise that the Ministry observe the functioning of the auction markets, and carefully scrutinize any localities where the number of bidders is systematically low. As discussed further below, the Ministry could, for example, retain a small number of sales exclusively for small businesses to ensure that they do not exit. (These sales need not be used for pricing stumpage under long-term tenure.)

In terms of strategic bidding, it might seem that auctioning a large volume is the critical factor in promoting a well functioning market. However, even with the current volume auctioned under the small business program, hundreds of auctions can be used to estimate the market-based pricing equation. Thus, the incentive for strategic bidding in any one auction is already small, without any increase in volume. Even if there were no reserve price and bids were zero at a given auction, that auction would have negligible impact on the pricing equation. The only way that strategic bidding could have a substantial impact on prices is if prices were systematically reduced in a given area over several years. To evaluate this concern, we argue that equation specification, rather than the total amount of volume auctioned, is the key factor in mitigating this effect. So long as the model is properly specified and the auction volume is sufficient for statistical accuracy, the incentives for strategic manipulation will be small.

To properly evaluate the incentives of a collusive group to manipulate auction prices we must pose the following question: how would lower auction prices in a given locality (district) affect stumpage prices that *licensees bidding in that district* face. Lower auction prices in a district feed back into that district's stumpage fees by changing the coefficients of the equation used in the equation-based pricing system. We focus on the effects on "own district" stumpage prices, because this is the most conservative approach: the effects of one district's manipulation on other districts' stumpage prices will always be smaller than on the "own district" prices (as illustrated in Appendix B).

To proceed, we start with a dataset of auctions from the Interior, and then create 31 new auction datasets, corresponding to the 31 districts. In each dataset, we multiply the auction prices in a single district by 0.9, corresponding to a 10 percent reduction in the district-specific price. Thus, the new dataset reflects a world where bidders in that district somehow conspired to keep prices 10 percent lower. Then, for each dataset, we re-estimate the equation for the equation-based pricing system, and in doing, estimate the equation that would have been used to set prices for stumpage under long-term tenure in a world of collusion. Finally, we calculate how much lower the tenure prices would have been using the "anti-competitive" equation as opposed to the actual one. In Appendix B, we present our results. We find that in 26 out of 31 districts, as a result of a 10 percent reduction in prices over a three-year period, the district would see less than a 3 percent reduction in stumpage fees, and in 13 out of 31 districts, the effect would be a price reduction below 1 percent . This implies that most districts would have to maintain substantial collusive power, cutting auction prices in half or more over the course of three years, in order to have a significant impact on their own stumpage fees. Even for the 5 districts with somewhat greater incentives to manipulate, none sees more than a 6.2 percent reduction. We have determined that slight modifications to the proposed Interior equation could substantially mitigate the incentives for manipulation for those 5 districts, and so we expect that going forward, the incentives to manipulate would be minimal.

We now turn to an overall evaluation of the likelihood that a licensee will attempt to manipulate auction prices in order to lower stumpage fees. We have established that any collusive activity would have to be substantial (cutting prices on the order of at least 50 percent for three years) to have a significant impact on licensee prices. We now argue that this is unlikely. First of all, the reserve (or "upset") price will constrain the minimum bid in any given auction. Although eventually, strategic bidding could reduce the reserve price as well, the proposed reforms call for lower bounds on reserve prices, and the reserve price would adjust only slowly to collusive behavior. Second, there are a variety of competitors, including mills and loggers, who bid in the auctions. In sealed-bid auctions, licensees have no opportunity to respond to a "surprise" bid by a logger. Given the risk of losing the auction, just the possibility of a new competitor serves to keep bidding aggressive. And, if auction prices are 50 percent below fair market value or are selling at the reserve price, even isolated areas of the interior might attract entrants, and it would become economically viable to transport logs longer distances, so that bids might come in from unexpected competitors. Third, with auction prices so far below market, it would also be very tempting for a licensee to "cheat" on a collusive agreement by submitting a higher bid, or making a secret deal with a logger. Since the prices mills pay loggers are not publicly observed, it will be difficult for mills to "police" each other in any sort of collusive agreement to keep log prices low. Fourth, the risk of being detected in a collusive endeavor of this scope and magnitude is probably large relative to the benefits (for example, loggers would need to be coerced into bidding low prices, and the licensees would always run the risk that a disgruntled logger would alert authorities). Finally, the Ministry can monitor the competitiveness of auctions, and take appropriate action if there is a suspicion of collusion. As described in more detail below, one possibility would be to maintain a small number of small-business set-aside sales, sales that would *not* be used to price stumpage, but sales that would serve to keep small loggers active and in business, so that they would continue to bid in the auctions.

Given all of these factors, we do not find it plausible that collusion significant enough to have an important impact on stumpage fees could be sustained, and we conclude that strategic manipulation is not likely. Furthermore, we believe that if the Ministry follows the suggestions outlined above for setting the specification and monitoring for anti-competitive behavior, the possibility for strategic manipulation should not be an important concern.

5 LOCAL MARKET POWER

Given the difficulty of transporting logs great distances, local market power within geographical areas may distort prices, especially in the Interior, where transportation is more difficult than on the Coast. If such market power is exercised, timber prices will tend to be biased downward as either the local logging market or the local milling market becomes more concentrated. Large bidders can reduce auction prices by bidding less aggressively. The incentive to do so is greatest when competition is weak, so that the less aggressive bidding results in a significant drop in prices and only a modest drop in the quantity won. Similarly, a large mill has an incentive to reduce its demand for logs if doing so results in a large price drop with only a modest drop in the quantity of logs it is able to buy. (Note that if several licensees engage in the strategy of reducing their demand for logs by cutting output, reduced exports from British Columbia will raise world prices for lumber.)

Mills with long-term tenures have an additional incentive to reduce auction prices. The lower auction prices reduce the stumpage fees paid for timber under long-term tenures. However, since the stumpage fees are calculated from auction sales throughout the entire region—Interior or Coast—this is not a local market power issue, but a regional market power issue. Hence, so long as milling is not excessively concentrated over the entire region, then this potential price distortion is unlikely to be important. Above, we provided evidence that even if all of the potential bidders in a local auction market reduce their bids, the effect on stumpage fees is small.

Now consider more precise evidence about the possibility that large companies can exercise local market power throughout the geographic areas where they operate. Before beginning, we note that there are several challenges in analyzing such market power. Because the main concern is whether market power leads to lower prices at auctions, we need to consider two types of bidders, loggers and mills. Currently, there are a number of small logging firms that bid on small business sales. These firms affect prices at auctions, both directly (when they win) and indirectly, because in a sealed bid auction, all firms bid more aggressively when they perceive that there is a chance that loggers will participate. However, logging firms must sell their logs, and they typically sell them to local mills. Thus, local mills can potentially exercise market power in two ways: they can reduce their overall production, thus reducing the demand for logs in the local market, and they can bid less aggressively in the auctions. The first strategy has potential problems, because for loggers to anticipate low prices from mills, they must anticipate that they will be unable to sell the logs to mills one to two years in the future. It may be difficult for mills to commit to cut production one to two years in the future. As we have argued above, the second method may be less likely due to the small effect of local auction prices on stumpage fees, and because of the potential for logger participation in the auctions, where mills may not be able to commit not to buy from loggers several years in the future.

With these considerations in mind, a second challenge is to define the relevant geographic area for market power. When analyzing the potential for strategic bidding in auctions *without* any reductions in the output of local mills, we look at market power at the district level, because for such strategic bidding to be effective, most local participants would need to be involved. However, to assess the ability of a large company to affect prices by cutting back its demand, we must consider this firm's effect on the entire area where it operates mills, and analyze its share of overall processing capacity. Thus, we proceed by analyzing concentration at the level of the Forest Region. The Forest Region is appropriate given that most major licensees have focused their operations in one or two Forest Regions.

However, we caution that due to the issues associated with the participation of loggers outlined above, standard measures of market concentration based on mill capacity may be conservative in this context. Nonetheless, such measures of concentration provide a useful upper bound on the extent of any potential problems due to concentration.

To gauge the extent of concentration and local market power in the B.C. Timber Industry, we first look at the breakdown of Major Licensee's market shares in each Forest Region. We then use the Herfindahl-Hirschman Index (HHI) as our measure of concentration, where the HHI is 10,000 times the sum of squared market shares in a specified market, to further explore the extent of regional market power. We begin by considering the major licensees' market shares of mill capacity in each Region. Tables C1 and C2 in Appendix C contain this data.

In the Coast, we find that no single licensee has considerable market share. Instead, there are three Majors, each with market shares of between 15 and 22 percent. The Interior regions are similar. In particular, each region contains three major firms with roughly equal capacity shares. Two Interior regions, Prince George and Prince Rupert, seem more concentrated than the others. In Prince George, Firm A has a 41 percent share, and three Majors control nearly 64 percent of total capacity in Prince Rupert. We now calculate HHIs as a measure of concentration in each forest region. Table 3 contains these results.

TABLE 3. REGIONAL HHI USING ANNUAL MILL CAPACITY (BOARD FEET)

Forest Region	***HHI***	***Level of Concentration***
Vancouver	1315.5	Moderate
Cariboo	1465.1	Moderate
Kamloops	1296.0	Moderate
Nelson	1876.0	High
Prince George	2200.2	High
Prince Rupert	1978.2	High

To make sense of the HHI numbers, consider the Merger Guidelines of the U.S. Department of Justice and the U.S. Federal Trade Commission. These guidelines use HHIs to define three levels of industry concentration: low, moderate, and high. In particular, if the HHI is below 1000, the industry is unconcentrated. If the HHI is between 1000 and 1800, then the industry is moderately concentrated. If the HHI is over 1800, then the industry is highly concentrated. The HHI is used as a preliminary tool for determining incremental market power that could be gained through a potential merger. Potential mergers resulting in a high level of concentration receive the most attention; those resulting in low are typically approved without further analysis. Following these guidelines, we characterize concentration in each of the Forest Regions. Three markets are moderately concentrated, and three are highly concentrated. Nelson, Prince George, and Prince Rupert are the highly concentrated markets, according to the guidelines.[6] Note, however, that the designation of “high concentration” does not necessarily mean that market power is a problem; it simply means that greater scrutiny is required to properly assess competition in those markets. In this case, the participation of loggers in the auction markets should be considered a factor that mitigates the ability of firms to exercise market power.

In addition, the concentration numbers above may be overstated. We are assuming that each region is a distinct market. To the extent that logs can be economically transported across regions, the relevant markets expand and the HHIs fall. In most cases, if we assumed that transportation between adjacent regions was possible the concentration level would fall considerably. Table 3 displays the worst-case situation where there is the same large Licensee in each of two concentrated regions. In particular, Prince George and Prince Rupert are adjacent regions. Thus, the transportation of logs between those regions causes concentration to fall. But Prince George and Prince Rupert share a common major licensee, which would inhibit the decrease in concentration. We therefore analyze the extent to which regional competition will reduce concentration when a major is located in both regions.

[6] The concentration in Prince Rupert may be higher than indicated, because one of the Major Licensees owns partial share in a smaller mill, and that partial ownership was not included in our data.

TABLE 4. CONCENTRATION IN ADJACENT INTERIOR REGIONS

Combined Region	***HHI for Combined Regions***	***Level of Concentration***
Cariboo-Kamloops	904.7	Low
Cariboo-Prince George	1421.6	Moderate
Prince George-Prince Rupert	1749.2	Moderate

Table 4 shows that regional competition greatly decreases concentration in the Interior, even when a Major Licensee owns mills in both regions. Thus, if regional movement of logs already exists, concentration is lower than what Table 3 suggested. Regional competition should also be encouraged in the future, because it will further improve competition in the Interior.

6 ROLE OF THE LOG MARKET

The log market and timber markets are closely tied. Prices for auctioned timber and stumpage fees for non-auctioned timber both should reflect current log prices. The timber auctions will benefit from a more efficient log market. Similarly, more efficient timber auctions will enhance the log market. Hence, complementary steps should be taken to improve the efficiency of the log market. These would include:

- Reporting of volume and prices in the log market, whenever possible.
- Reforming the system for grading logs in the Interior.

With a more active and efficient log market, timber prices may be estimated more precisely. As a result, less volume need be auctioned to achieve the same level of statistical precision for stumpage fees on non-auctioned tenures.

The development of log markets in the Interior is challenging. The profile and species mix for a large portion of the harvest along with transportation costs make log markets fairly localized. Under such circumstances, it is possible for the local log market to become captured by a dominant local buyer. Then dealing with non-competitive factors in the log market may be an important factor for improving the efficiency of the timber market.

7 SHOULD MAJOR LICENSEES BE ABLE TO BID?

Currently, the auctions are restricted to small businesses and limits are placed on the number of stands that can be won by a single bidder. Holders of long-term tenures (“major licensees”) are not eligible to bid on these sales. These restrictions can actually serve to increase auction competition and prices, so long as there are not significant economies of scale in logging that cannot be realized as a result of the restrictions. In the absence of scale economies, the restrictions reduce concentration in logging, increase the number of bidders in the auctions, and hence increase auction prices.

The experience from U.S. spectrum auctions conducted from 1994 to the present supports the view that restricting an auction to small businesses can increase competition and revenues. In many instances, auctions restricted to small businesses were more competitive and resulted in prices that were above the prices paid in auctions where both small and large businesses could bid. This was the case even in settings where significant scale economies were present.

If there is a substantial increase in the volume auctioned, then it probably does make sense to allow Major licensees to bid. At least in the short-run, entry into the logging market may be insufficient to handle the expanded volume. However, in the interior most logging is contracted out, and on the coast about one-half of the logging activity is contracted out. Hence, these contractors may have sufficient logging capacity, so that the Majors would not have to bid directly.

The only concern is whether direct participation by the Majors will over time make the logging industry more concentrated. It is conceivable that the Majors would ultimately drive the small loggers out of business. Certainly, they would be able to by refusing to buy logs from small loggers. However, they have little incentive to do so, at least from the perspective of short-run profits. The incentive for the Majors is to procure logs at least cost. If a Major can buy logs from small loggers at a price that is no higher than what it would cost the Major to do the logging directly, then the Major has every incentive to buy from the small logger. Only if a Major anticipated substantially lower long-run prices at auction would it be willing to suffer losses by refusing to buy from small loggers. Furthermore, for such refusals to drive small loggers out of business, several Majors would likely have to coordinate on the same strategy, and a Major facing a supply shortage would find it especially costly to refuse logs.

It should be possible to monitor closely the state of the industry, and to respond if too many loggers exit the industry. One possible strategy is to reserve the right to sell some part of the volume to only small businesses, even if that volume is not used in setting the prices.

On the other hand, there are a number of administrative costs associated with maintaining the small business program, and proposing it presents a number of complications. Thus, it may make sense to keep a close watch on the industry and respond only if a problem presents itself.

8 Speculation

Speculation is the problem of bids being artificially high, because the bidder only intends to cut in situations where the log price turns out to be unusually high. The winning bidder simply walks away from the stand if log prices are low. Since stumpage fees are only paid for cut timber, not cutting results in no fees.

There are numerous ways to mitigate speculation:

- Require a sufficient deposit, which is then forfeited if sufficient logs are not cut.
- Do not allow license extensions.
- Use variable fees in all cases, so that the stumpage fee (upset plus bonus) falls with log prices.
- Use a short license duration.
- Only include an auction outcome in the dataset if a sufficient fraction of the logs in the stand were cut.

One should expect fewer logs to be cut when log prices are low. This occurs both in the auctioned stands and in the long-term tenures. Hence, the fact that cutting declines when log prices are low is not a clear indication of speculation. Nonetheless, speculation is a potential problem that should be monitored. The instruments above should be used as needed to address the problem.

9 Marginal Pricing

In a competitive market, prices are determined at the margin. That is, the price is set at the point where the supply and demand curves cross: where the marginal value from another unit is just equal to the marginal cost of supplying that unit. All units are sold at this market clearing price.

The proposed approach for determining stumpage fees on long-term tenures effectively implements the outcome of a competitive market. The auction determines the clearing price, and then this clearing price is applied, recognizing the differences across stands, to all timber.

Some may argue that marginal pricing may bias prices upward. In times of scarcity, mills may be willing to pay very high prices for logs in order to keep the mills running. However, this is simply how competitive markets work—in times of scarcity, prices are high, and in times of surplus, prices are low. It is efficient to charge this marginal price for each unit sold.

One legitimate concern with the pricing approach is that the upset price may bias prices upward by setting a floor on how low prices can fall in times of surplus. Prices cannot fall below the upset price, and yet there is no restriction on how high prices may rise. Prices are biased upward to the extent that there is a significant fraction of unsold stands. An unsold stand means that no bidder was willing to submit a bid at or above the upset price. The market price for that stand is presumably below the upset price. This low-price data point is excluded from the dataset, since no sale occurred. It is easy to determine the extent of this problem by monitoring the frequency of unsold stands. If stands are frequently unsold, then reducing upset prices can mitigate the problem. However, this should be done only in extreme situations to avoid gaming problems. If bidders know there is a policy to reduce the upset rate in lock step with a specified level of unsold tenders there is an incentive to collectively restrict bidding to get the upsets lowered. This should be avoided. Instead, the sale can be repackaged to make it more attractive or simply re-tendered at a more appropriate time. Alternatively, the estimation can be corrected to take into account the upward bias in prices caused by the elimination of low-price data points.

Due to large fixed costs of operating a mill, a mill with excess capacity would be willing to pay a high price for a particular stand of timber, even though the mill would be unprofitable if it paid that price for all of its timber. It is efficient for prices to adjust in this way with the scarcity of timber. In practice, does this mean that auction prices will always be determined solely by the willingness-to-pay of a mill with excess capacity? Not quite. When trading restrictions are removed, a mill with excess capacity can also procure timber from other Majors and loggers. Another mill might find that the cost of processing the last few logs is particularly high, and it can sell those logs to the mill with excess capacity. Thus, whenever one mill is willing to pay "unreasonably" high prices for logs, others should find it profitable to sell to it. An active log market will tend to dampen the excessively high auction prices. In addition, if prices are set "too high" due to overcapacity, these high prices will encourage efficient capacity rationalization.

10 Spot Pricing vs. Long-Term Pricing

Under the proposed pricing plan, the stumpage fees under long-term tenures will be the spot price as estimated from the data on auctioned stands. This is the best estimate of what the price would be if it were auctioned at the time of cutting. It is the price that would be charged in an efficient and competitive spot market.

The only disadvantage of charging the spot price is that this price is more volatile than a long-term price. One of the advantages of long-term contracts is the ability to hedge price risk by locking-in long-term prices. Indeed, in some other markets (e.g. electricity), suppliers offer long-term contracts guaranteeing some range of quantity at a given price. That price is typically not the spot price, and so the buyer may end up paying more or less than the spot price at the time the transaction takes place.

Under the proposed pricing plans, long-term contracts of this sort are not offered. Even though the tenure-holder has a long-term guarantee on quantity, prices are not locked in. Thus, spot prices are the correct prices to use. If, hypothetically speaking, long-term price guarantees were to be offered, the market long-term price could only be determined by holding an auction for a similar contract, that is, by auctioning off a long-term quantity guarantee at a fixed price.

The proposed system (and the existing system) do not offer the ability to hedge price risk through long-term contracts. However, for a mill that transforms logs into lumber and other products, risk is minimized by paying timber prices that move with the prices of lumber and other finished products. The timber spot price does just that.

Even without long-term supply contracts at a fixed price, long-term tenures have several economic advantages, most notably encouraging efficient investment in the timber resource, guaranteeing a steady supply of timber for its mills, and promoting private-industry decisions on where and when to cut. Spot pricing for the long-term tenures retains and complements all these advantages by sending the right price signals for Majors to make efficient investment and cutting decisions.

11 Tenure Obligation Adjustments

There are important differences in the obligations of a long-term tenure licensee and those of a logger of auctioned timber. Costs that are borne by the licensee under long-term tenures, but are borne by the government for auctioned timber, must be subtracted from the spot price to determine the stumpage fee for long-term tenures. The magnitude of these adjustments will be a source of debate. Hence, to the extent possible it will be important to use transparent and objective methods in determining these costs.

Since all these costs are borne by the government on the auctioned timber, one approach would be to determine these costs for the auctioned timber, and then estimate the costs for the timber under long-term tenure from the government's costs, taking into account differences in the important determinants of costs across stands. Wherever possible, the government's costs should be determined from competitive bid for the required services (e.g., road building). The goal of the government should be to perform the required services at least cost.

Under this approach long term tenure holders will at times be under-compensated for actual costs and sometimes over-compensated, but on average the compensation should equal the actual costs of a long-term tenure licensee meeting obligations at minimum cost. The decisions of long-term tenure licensees will not be distorted if the cost model produces good estimates of actual costs.

A second approach is to estimate costs from cost data of companies on long-term tenures. This approach should only be used for cost components that cannot be reasonably estimated from government costs for auctioned timber. Further, it should only be used for cost components where it is easy to verify that the long-term tenure holder has indeed sought to minimize the cost (e.g., by the use of competitive bid).

12 Conclusion

We strongly support British Columbia's proposed market reforms to improve its pricing of timber. The market-based approach enables efficient cutting of timber, efficient investment in developing timber lands, and minimizes the impact of government decisions on timber pricing. The package of reforms eliminates trade distortions, allows for efficient entry and exit, and promotes efficient specialization. Companies see the correct price signals and have the flexibility to respond with efficient operating and investment decisions.

A critical issue is how much volume should be auctioned. To reduce the government's impact on timber prices, it is important not to auction too much. However, three factors—statistical precision, market thickness, and absence of strategic bidding—place a limit on the minimum auction volume that achieves reliable market-based prices for all timber. We find that most gains in statistical precision are obtained with moderate auction volume, on the order of 15 percent, and the gains in terms of precision from auctioning more than 15 percent diminish rapidly. In terms of market thickness, volumes in this range should be sufficient to generate competitive auctions, so long as the small loggers do not exit the market. Finally, the primary issue in terms of strategic bidding is model specification, not volume, and our analysis suggests that with an appropriately specified model, strategic bidding should not be a major concern.

Thus, we believe that any potential problems with statistical precision, market thickness, and strategic bidding can be addressed by auctioning a volume of about 15 percent, and we see little reason to believe that there will be substantial improvement in the functioning of the markets at greater levels of volume. Rather, the higher auctioned volume would serve to increase the government's impact on the market, and thereby increase the force of politics rather than economics in determining timber prices. The auctioned volume should be kept low enough to ensure that the long-term tenure holder's dynamic cutting decisions determine prices, not the short-term supply decisions of the Crown.

We strongly favor a system where market forces determine the total volume harvested. This objective is achieved under the proposed system, where minimum annual cut restrictions are removed, but long-term tenure-holders retain decision-making for the timing of harvests for a substantial portion of the volume.

APPENDIX A. MONTE CARLO STUDY TO ASSESS STATISTICAL PRECISION

This Appendix provides the details for the Monte Carlo study of statistical precision outlined in Section 4.1.

To conduct the analysis, we must generate datasets that have the characteristics that would be present in true auction datasets. We begin by generating the following regression variables with standard normal distributions, corrected with the appropriate means and standard deviations found in the SBFEP interior auctions for years 1998, 1999, and 2000. We present these variables, their means, and their standard deviations in Table A1.

TABLE A1. VARIABLES GENERATED INDEPENDENTLY FROM A NORMAL DENSITY

Variable	*Mean*	*Standard Deviation*
log(net cruise volume)	7.016	1.763
log(development cost)	0.423	1.146
log(cycle)	1.263	0.399
log(number of bidders)	1.096	0.71

For example, to obtain our observations for the log of net cruise volume, we generate a standard normal random variable, multiply its values by 1.763, and then add 7.016 to those values. Then, to get values of net cruise value, we take the exponential of log (net cruise volume).

In the interior, the percentages of timber characterized by fire damage, “blow down” damage, cable yarding, helicopter extraction, and horse extraction all affect the value of a timber stand. These variables, often take on values of 0, and when they are not zero sometimes take on most of their values as ones. When they are not 0 or 1, however, these variables are generally mound shaped. For these reasons, we generate such variables by first creating a normal variable with the same characteristics as the nonzero, non-one observations we see in the SBFEP data. Then we generate two more random variables that are uniformly distributed on the interval (0,1) to adjust the normally distributed observations to zero or one approximately as often as in the SBFEP data. To give an example, of the 4787 observations in the SBFEP dataset, only 156 have horse extraction percentages greater than zero. Further, 119 of those 156 nonzero observations are 100 percent. The remaining observations are roughly mound shaped with mean .714 and standard deviation equal .215. Thus, to generate the horse extraction variable we first create a normally distributed random variable with mean .714 and standard deviation of .215. We then create a uniformly distributed variable on the interval (0,1) and change the observations of our horse variable to zero every time that uniform is less than .967 (1 - 156/4787 = .967). For the remaining positive observations, we create another uniform(0,1) variable and change the remaining nonzero horse observations to 1 if that uniform random variable is less than .763 (119/156 = .763). We perform similar processes to generate the fire damage, blow down damage, cable yarding, and helicopter extraction variables based on the characteristics of those variables in the SBFEP dataset for years 1998, 1999, and 2000.

In creating an accurate random dataset to use in the model, we also capture much of the multicolinearity that exists in the SBFEP data. Below, we present summary tables for the four variables that demonstrate the most multicolinearity of those in the SBFEP regression model. In addition, we present a table showing the summary statistics of the residuals from the regressions run on those four variables.

In generating our observations for slope, the natural log of value per tree (lnvpt), selling price index (spi), and value per hectare divided by 1000 (vph_1000) we use the other explanatory variables that we generated above. The regression equations we use are those presented in Tables 2 through 5. For each prediction we add an observation from a normally distributed random variable with the same mean and standard deviation as the residuals from the appropriate regression equation. We present these summary statistics in Table A6 below.

TABLE A2. REGRESSION WITH SLOPE AS DEPENDENT VARIABLE

Variable	***Coefficient***	***Standard Error***	***t-Statistic***
cable yard %	31.687	1.705	18.59
Heli Extraction %	-14.946	2.365	-6.32
horse Extraction %	-17.858	2.411	-7.41
log (number bidders)	-1.553	.553	-2.81
constant	19.227	.875	21.99
R^2	.457		
Adj-R^2	.453		
Sample	570		

TABLE A3. REGRESSION WITH LNVPT AS DEPENDENT VARIABLE

Variable	***Coefficient***	***Standard Error***	***t-Statistic***
development cost	.014	.008	1.69
net cruise value/1000	.006	.003	2.17
slope	.011	.002	4.84
blowdown %	.296	.178	1.66
fire damage%	-.219	.132	-1.66
cable yard %	.314	.115	2.74
heli extraction %	.293	.130	2.25
horse extraction %	.364	.134	2.71
cycle	-.062	.0112	-5.53
log(number bidders)	-.027	.030	-0.91
constant	-.771	.086	-8.99
R^2	0.188		
Adj-R^2	0.173		
Sample	570		

TABLE A4. REGRESSION WITH SPI AS DEPENDENT VARIABLE

Variable	*Coefficient*	*Standard Error*	*t-Statistic*
development cost	-1.185	.283	-4.19
slope	.345	.072	4.78
log(value per tree)	8.485	1.404	6.05
blowdown %	-16.202	5.986	-2.71
fire damage %	-7.228	4.434	-1.63
cable yard %	-8.051	3.827	-2.10
heli extraction %	19.550	4.333	4.51
cycle	-1.183	.376	-3.14
log (number bidders)	1.694	.985	1.72
constant	118.053	2.827	41.76
R^2	0.199		
Adj-R^2	0.186		
Sample	570		

TABLE A5. REGRESSION WITH VPH_1000 AS DEPENDENT VARIABLE

Variable	*Coefficient*	*Standard Error*	*t-Statistic*
development cost	-.010	.002	-5.96
net cruise value/1000	.002	.001	4.81
log (value per tree)	.090	.008	11.59
blowdown %	.170	.034	4.96
fire damage %	-.095	.025	-3.79
cable yard%	.068	.018	3.76
heli extraction %	.047	.024	1.98
horse extraction %	-.067	.025	-2.73
constant	.334	.010	32.86
R^2	0.353		
Adj-R^2	0.344		
Sample	570		

TABLE A6. SUMMARY STATISTICS FOR RESIDUALS

Variable	*Mean*	*Standard Deviation*	*Min*	*Max*
slope residuals	1.00e-14	8.905246	-17.9137	35.46854
lnvpt residuals	8.96e-17	.4654519	-1.623321	1.284814
spi residuals	-3.45e-14	15.60856	-67.22772	54.92692
vph_1000 residuals	-4.30e-17	.0895781	-.3392292	.2788185

With our regression variables defined, we then generate observations of bids according to the regression equation that we estimate from a sample of 901 observations in the SBFEP dataset for years 1998, 1999, and 2000. This regression is displayed in Table A7.

TABLE A7. REGRESSION WITH DEFLATED BID AS LHS VARIABLE

Variable	*Coefficient*	*Standard Error*	*t-Statistic*
selling price index	.229	.021	11.04
development cost	-.873	.103	-8.51
value per hectare/1000	11.632	2.383	4.88
net cruise value/1000	.1845	.048	3.87
slope	-.061	.037	-1.63
log(value per tree)	7.802	.719	10.85
blowdown %	-13.972	2.372	-5.89
fire damage %	-18.914	2.347	-8.06
cable yard %	-11.986	1.883	-6.37
heli extraction %	-37.286	2.172	-17.17
horse extraction %	-12.204	1.297	-9.41
cycle	-1.9343	.199	-9.74
log (number bidders)	5.854	.454	12.91
constant	23.668	2.789	8.49
R^2	.62		
Adj-R^2	.62		
Sample	901		

The residuals from this regression have a mean of -2.4×10^{-14} and standard deviation of 9.41. After applying the coefficients in Table A7 to the respective variables, we then set negative bid values to zero. This is justified because a timber stand with negative value would receive no bids, and therefore would have a final bid price of zero. For the remaining stands, we summarize the bid observations, and find them to have mean value of approximately 40 and standard deviation of approximately 26.[7] Because the nonzero bids in years 1998 through 2000 have a mean of 37.2 and standard deviation of 17.1, we find that the characteristics of the true bids are accurately reflected in our data. Thus, we generate our "true" bids, by taking the bids generated by the equation in Table A7, and adding an error component that is normally distributed with zero mean and 9.41 standard deviation. The standard deviation of 9.41 is conservative, because the regression that determines that standard deviation is based on a sample size of only 6.5 percent. Increasing the sample size even to 13 percent will likely allow the regression to better predict all types of timber stands in the data, and therefore, shrink the errors around the average predicted value. The extent to which increased sample size shrink these errors in the *actual* dataset is, of course, unknown. We therefore proceed using 9.41 as our standard deviation, noting that this value will most likely decrease with an increase in sample size (although the gains will probably be diminishing in volume).

[7] We say "approximately" because these moments will vary slightly with the number of simulations, and the "seed" that is used in the study. The seed refers to the setting that is used as a starting point to generate the sampled data. We set the seed equal 2023319716, and used Stata, release 7.0 as our statistical program in this analysis.

TABLE A8. RESULTS FROM 100 MONTE CARLO SIMULATIONS

Volume (%)	*Mean R^2*	*Average 95% Conf. Int. Size*	*Incremental Improvement*
10	.842	2.6874	
15	.840	2.1933	0.4941
20	.841	1.8971	0.2962
25	.841	1.6961	0.2010
30	.841	1.5474	0.1487
35	.841	1.4328	0.1146
40	.840	1.3364	0.0964
45	.840	1.2601	0.0763
50	.841	1.1964	0.0637

Table A8 displays statistics that assess the ability of the regression to accurately predict the true regression coefficients. R^2 measures the ability of the regression to explain variation in the equation's dependent variable (in this case stumpage) with the explanatory variables. Higher values of R^2 indicate that the regression explains a larger percent of the movement in stumpage prices, and therefore, the estimated regression shows an improvement in its "fit" to the data. The 95 percent confidence interval measures the ability of our regression to approximate the true stumpage equation.[8] As the size of the confidence interval decreases, then with 95 percent confidence, the true regression coefficients lie closer to the estimated coefficients.

A more specific review of the numerical values in Table A8 follows. For a sample volume of 10 percent, the average R^2 was .842, indicating that on average the explanatory variables in the regression explained 84.2 percent of the variation in stumpage rates. Now, note the R^2 values in Table 8 tend to stay constant with increases in the sample size. This means that increasing the sample size has no added advantage in explaining variation in stumpage. This is not surprising because with the volume characteristics and total yearly volume we specified for this simulation, a sample size of approximately 2400 observations results when volume is 10 percent. For most regressions that do not suffer from major specification problems, a sample of 2400 observations is large enough to ensure a reasonably good fit.

Now recall that the average 95 percent confidence interval size measures the deviation of the best-fit regression line from the true regression line with 95 percent likelihood. To give an example, suppose that the sample volume is 10 percent. In addition, consider values of the explanatory variables that, when inserted into the estimated regression, would predict a stumpage rate of $50. The 95 percent confidence interval around this predicted rate is $50 \pm 2.69/2 = (48.66, 51.35)$, indicating that we are 95 percent confident that if we inserted the same values of the explanatory variables into the *true* regression equation, we would predict a bid between $48.66 and $51.35. We generate such confidence intervals so that we can gauge the accuracy of our forecasts, and a decrease in the size of a confidence interval indicates an improvement in estimation. As stated above, when the confidence interval shrinks, the regression equation lies closer to the *true* stumpage equation.

[8] The confidence interval is four times the standard prediction error of the regression. This statistic measures error in the model that arises because the estimated parameters may not perfectly correspond to the true parameters unless the sample size becomes infinite.

APPENDIX B. ANALYSIS OF STRATEGIC BIDDING

This Appendix describes the analysis supporting our conclusions about the incentives for strategic manipulation of auction prices by licensees.

We proceed as follows. Starting with a dataset of auctions from the Interior, we create 31 new auction datasets, corresponding to the 31 districts. In each dataset, we multiply the auction prices in a single district by 0.9, corresponding to a 10% reduction in the district specific price. Thus, the new dataset reflects a world where bidders in that district conspired to keep prices 10% lower. Then, for each dataset, we re-estimate the equation for the equation-based pricing system (shown in Table A7), and in so doing, estimate the equation that would have been used to set prices for stumpage under long-term tenure in a world of collusion. Finally, we calculate how much lower the tenure prices would have been using the "anti-competitive" equation as opposed to the actual one.

Our results are summarized in Table B1. The first column indicates the effect that price reductions in one's own district can have on that district's tenure prices. For example, as a 10 percent reduction in bid prices in the 100 Mile House Forest District, tenure-holders in that district would pay 1.9% less for stumpage. Further, if one of the other districts (randomly selected) reduced *its own* auction prices by 10%, the expected change in stumpage prices for 100 Mile House Forest District tenure holders would be only 0.27%. Notice that for most districts, the effect of a 10 percent reduction in *own district* auction prices on long-term tenure prices is on the order of 2% or less. A few exceptions are highlighted. Three of these exceptions are due to the effect of the Zone 9 dummy in the equation. Thus, it may be advisable to remove that dummy variable, because it appears to magnify the effect of collusion on the tenure prices. The other problem appears to be due to the Hemlock, Balsam, or Cedar dummy variable. Further exploration is required to see if there is another way to include this information without creating the opportunity for strategic manipulation.

To understand why specification plays an important role in creating incentives for strategic manipulation, consider the effect of including district specific dummy variables in the equation. If all bids in a particular district are reduced by $5, the estimated coefficient on the district's dummy would fall by about $5. More generally, there may be certain stand characteristics that are present only in a few districts. Then, the estimated coefficients of those stand characteristics respond similarly to a local price change, as would the district specific dummy. For this reason, the equation used in the equation-based system should avoid the use of dummy variables for small localities, and variables should be chosen in a way that they have explanatory power over multiple districts. These guidelines should not be difficult to follow, and the ministry could use a "manipulation test" of the type we propose here to verify that the final equation it chooses is not vulnerable to manipulation.

We caution that the numbers presented in this table are preliminary and probably represent a "worst-case" scenario, because the Ministry did not design the equation that we used with an eye towards minimizing opportunities for strategic pricing. If a few modifications to the equation are incorporated, we expect that the biggest possibilities for manipulation will be eliminated.

Finally, we caution that we have not addressed possibilities for inter-district collusion. Again, we expect that this will be more difficult to accomplish and will require more coordination, because the set of potential bidders (and especially the set of loggers) changes from district to district. At some point, it becomes difficult to organize such large-scale collusion without being detected.

TABLE B1. TENURE PRICE EFFECTS FROM AUCTION PRICE REDUCTIONS

District Name	*Predicted Reduction in Own District Tenure Price from a Reduction in Own District Auction Prices*	*Predicted Average Reduction in Tenure Prices as a Result of Reduction in Auction Prices in Other Districts*
100 Mile House	0.01951	0.00268
Arrow	0.00386	0.00321
Boundary	0.01544	0.00282
Bulkley-Cassiar	0.01396	0.00287
Chilcotin	0.02810	0.00240
Clearwater	0.01815	0.00273
Columbia	0.03653	0.00212
Cranbrook	0.00498	0.00317
Dawson Creek	**0.06221**	0.00126
Fort Nelson	0.00319	0.00323
Fort St. James	**0.01255**	0.00292
Fort St. John	0.04541	0.00182
Horsefly	0.00238	0.00325
Invermere	0.00349	0.00322
Kalum	**0.04585**	0.00181
Kamloops	0.01352	0.00288
Kispiox	0.02831	0.00239
Kootenay Lake	0.02061	0.00265
Lakes	0.01652	0.00278
Lillooet	0.01547	0.00282
MacKenzie	0.00063	0.00331
Merritt	0.00762	0.00308
Morice	0.00651	0.00312
Penticton	0.00221	0.00326
Prince George	0.02643	0.00245
Quesnel	0.01562	0.00281
Robson Valley	0.00115	0.00330
Salmon Arm	**0.05367**	0.00154
Vanderhoof	0.00571	0.00314
Vernon	0.00419	0.00319
Williams Lake	0.00557	0.00315

APPENDIX C. MARKET SHARES OF MILL CAPACITY

TABLE C1. SHARE OF COASTAL MILL CAPACITY

Forest Region	***Licensee***	***Capacity (board feet)***	***Share of Capacity (%)***
Vancouver	A	638.4	14.9
	B	1,118.4	26.0
	C	710.4	16.5
	All Others	1,831.2	42.6

Source: B. C. Ministry of Forests

TABLE C2. SHARE OF MILL CAPACITY BY INTERIOR FOREST REGION

Forest Region	***Licensee***	***Capacity (board feet)***	***Share of Capacity (%)***
Cariboo	D	355.2	22.2
	E	314.4	19.6
	F	206.4	12.9
	All Others	724.8	45.3
Kamloops	A	494.4	25.1
	G	256.8	13.0
	F	328.8	16.7
	All Others	892.8	45.3
Nelson	H	523.2	33.7
	I	319.2	20.6
	J	235.2	15.2
	All Others	472.8	30.5
Prince George	K	1,836.0	40.6
	J	672.0	14.9
	L	573.6	12.7
	All Others	1435.2	31.8
Prince Rupert	M	261.6	15.3
	D	417.6	24.4
	K	410.4	24.0
	All Others	619.2	36.2

Source: B. C. Ministry of Forests