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An Application of System Dynamics Modeling

to

The Question of a Log Export Ban for Indonesia

with Comments on Illegal Logging

Richard Dudley ©

January 2002

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Abstract

System dynamics modeling allows us to examine various scenarios within a complex system. By using this approach we not only learn about the response of the system to test inputs which could never be tested in the real world, but we also learn to question our assumptions about the system itself. This leads to a better understand of its workings.

This paper presents a preliminary system dynamics investigation into the potential effects of a log export ban on the Indonesian forest sector. As a preliminary model its primary purpose is to help us better visualize potential effects of a log export ban rather than to predict, in detail, actual outcomes.

The model provides relatively simplistic overviews of the wood processing sector, demand – price feed back loops, forest standing stock and log availability, capacity of the harvest sector, as well as export demand, price and log exports. In spite of its apparent simplicity the model examines important feedbacks that must be understood if the effects of a log ban are to be properly examined.

Introduction

Indonesia's forestry sector has been in turmoil for the past several years following the removal of President Soeharto from power in May 1998. Since then there has been a major decentralization of governmental authority to the provinces and districts. This was done without careful planning of laws and regulations, including those related to natural resources. During this period of weakened legal control, there has been a substantial increase in the amount of illegal logging, so that in 2001 roughly 50% of the timber harvest was illegal. The illegal logging situation in Indonesia as of mid 2000 is well documented by Scotland et al (2000). For a discussion of possible causal links leading to increases in illegal logging see Dudley (2001).

A significant portion of the illegal harvest is thought to be exported. Consequently, some concerned agencies and NGOs have suggested a log export ban as a means of limiting illegal exports, thus reducing illegal logging. The idea of a ban on all exports to prevent exports of illegal logs might appear illogical, since one might expect that logs would merely be exported illegally. However, proponents of a complete log export ban believe that terminating <u>all</u> exports would make an export ban workable. In their view a partial ban (e.g. on certain species) would be ineffective since it could be easily defeated using phony documentation. With a total ban, any log leaving the country would be illegal and could thus be easily identified as such.

Several analysts have pointed out that there are many other ramifications of a log export ban. Most often cited are the loss of export tax revenue, and possible effects on the domestic timber related industries. The effects on domestic industry are generally considered either: good – due to increased access to cheaper raw materials, bad –a lack of competitiveness fostered by over protection, or both. Also, employment in the logging and wood processing sectors: might decrease – due to a decrease in log harvest, or might increase – due to a stimulation of the wood processing sector.

A meeting[1] held in September 2000, to discuss possible effects of an export ban included participants from industry, government, academia, NGOs, and donor and donor project representatives. Of the subjects discussed they agreed on 13 and disagreed on 28 items. Significantly, several items where no consensus could be reached were those which involved prediction of the outcomes of a log export ban.

Prediction of complex situations without an understandable and agreed upon framework is difficult. Illustrated herein, using the log export ban as an example, is one established approach for looking at this type of problem: system dynamics modeling.

Modeling Approach

Starting Point

The overall purpose of this model is to examine, in a preliminary way, the effect that a log export ban might have on the Indonesian logging and wood processing industries. A secondary purpose is to illustrate the utility of the system dynamics approach for this sort of policy analysis.

The starting point for this overview is a causal loop diagram – a type of rigorous picture model (Figure 1) modified from that presented in Dudley 2001. In this diagram four balancing

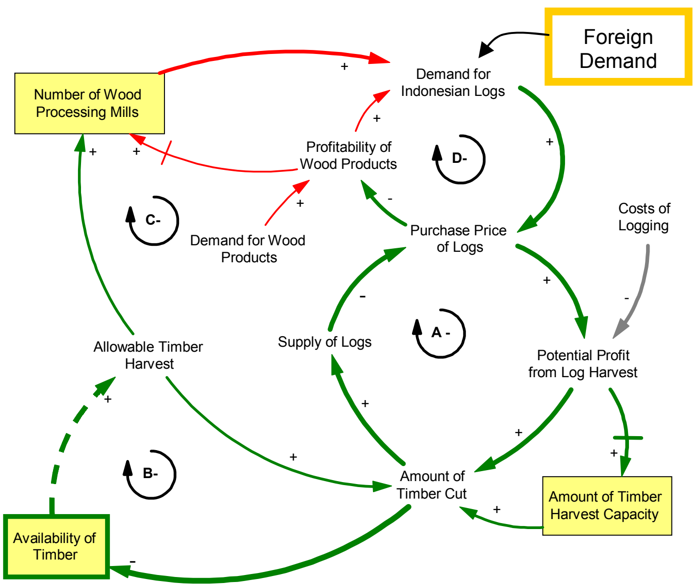

Figure 1. A causal loop diagram illustrating interconnections between the wood processing and logging sectors. Our interest is to investigate how foreign demand for logs might affect this system.

[1] Roundtable On Log Export Ban. 27 September 2000. World Bank Office, Jakarta. (meeting summary).

feedback loops are labeled. Loop A represents activity in the logging sector where log prices affect profit from logging which in turn affects the amount of timber cut which then affects prices. Loop B indicates the effect of timber harvest on timber available, which then, in operational forest management systems, effects an allowable timber harvest which affects amount of timber cut. Similarly, the much larger loop C indicates that allowable timber harvest will affect the number of wood processing mills which affects the demand for logs. This demand affects the purchase price of logs, affecting logging profits which influence the amount of timber cut. Loop D reflects how the demand for logs affects log price and profitability of wood products manufacture which will further affect log demand. Our real interest is in determining how this simple system is affected by foreign demand for logs.

This simplistic starting point helps to reveal many important questions especially when we think about the meaning of the connecting arrows. To what extent, for example, do low log prices improve profitability of wood product manufacture? At what log price do profits start to suffer? At what profitability level do mills start to expand? At what point would mills shut down?

Similarly we can envision several questions in the harvesting sector. How fast can the harvesting sector respond to changes in demand? Will log prices drop as harvesting increases? As forests become less abundant do harvest sector profits drop or do log prices rise enough to compensate for decreased availability?

These questions cannot be answered by the type of model presented in Figure 1. A quantified model is necessary to get a better feel for how these model components might behave under different circumstances.

Model structure

General Comments

The basic structure of the model consists of the following sectors:

1) links between product profitability and wood processing capacity,
2) links between domestic demand and log prices,
3) links between log supply and the profitability of logging,
4) links between profitability of logging and the size of the logging industry,
5) links between log exports, foreign demand, foreign price for Indonesian logs and its effect on domestic prices, and
6) the effect of logging on forest cover.

For simplicity we can visualize the model as depicting a forested area of 1 million ha with associated processing capacity. The model is initiated with a stable log harvest of 3 million m^3/year (or 3 m^3/ha/year), 1.5 million m^3/year is exported and the other half is processed by 1.5 million m^3/year of domestic processing capacity. Log prices are \$50/m^3 with logging cost accounting for half this. The selling price of wood products is set at \$100/m^3 of raw material used, giving an initial profit margin of \$50/m^3.

Note that wood processing capacity, domestic demand for logs and related components are measured in m^3/year not in m^3. Thus flows into and out of the relevant stocks are measured in terms of m^3/year/year, which reflects how fast the flow of logs is changing.

Wood Processing and Domestic Log Demand

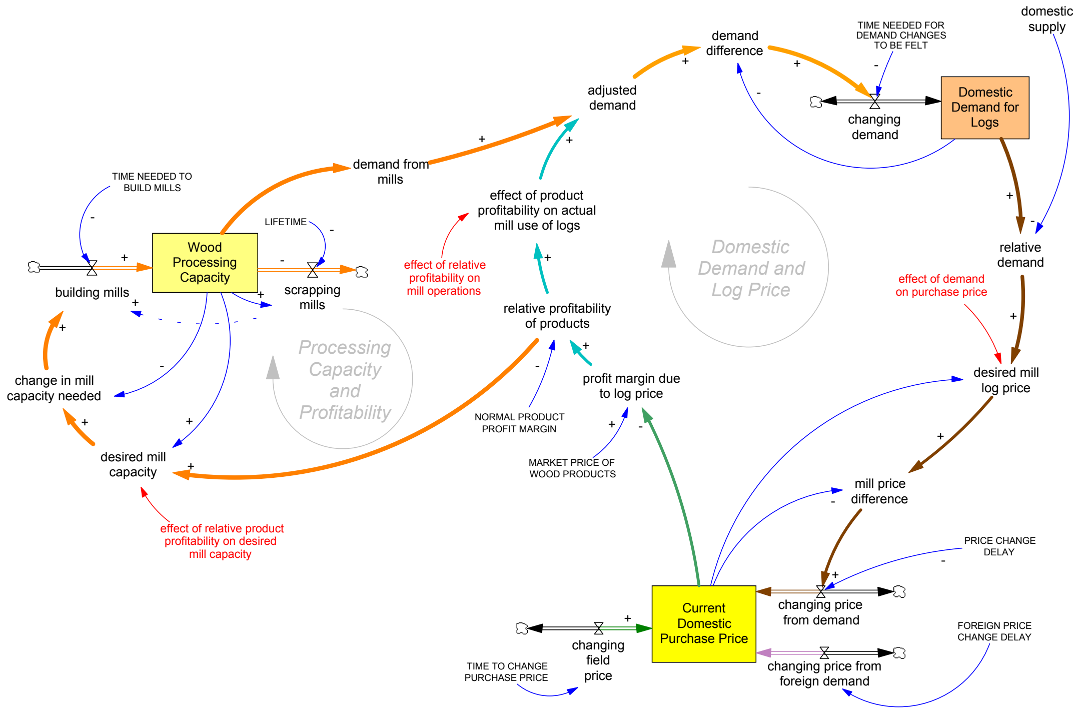

Figure 2. Wood Processing and Domestic Log Demand. Model components showing the link between domestic log processing capacity, domestic demand for logs and the current domestic purchase price for logs. Note that some model components have been removed for clarity.

Figure 2 presents that part of the model related to domestic log processing capacity, its effect on domestic log demand and the effect of demand on log price. In this conceptual view the *relative profitability of wood products*[2] determines the *desired mill capacity* of the processors. This desired capacity is gradually incorporated into the actual *wood processing capacity* as mills are built, expanded or improved. At the same time older or obsolete mills and equipment are scrapped. This gradually changing capacity creates a *demand from mills*.

Because wood processing capacity is not always fully used, the demand from the mills must be modified by some measure of capacity utilization. This is also dependent on the *relative profitability of products*. An *effect of product profitability on the actual mill use of logs*, in connection with *demand from mills* determines an *adjusted demand*. Because

[2] Items in italics are names of model components.

there is *time needed for demand changes to be felt,* actual *domestic demand for logs* changes more slowly than the *adjusted demand.*

Domestic demand for logs will affect price because demand may exceed *domestic supply* and sometimes supply may exceed demand. Thus the *relative demand* (the demand compared to supply) will effect the price the mills would like to pay for their logs: *the desired mill price*. This becomes one of several factors affecting the *current domestic log price* which in turn will affect the *profit margin due to log price* and overall profitability of wood product manufacture.

Three functions are used in this portion of the model. Functions often reflect areas where our knowledge of relationships between model components may need to be improved.

For example what is the actual relationship between product profitability and the desire to build new mills: *the effect of relative profit profitability on desired mill capacity*. At some level of profitability mill owners will merely be happy with their current mill capacity. At this point the effect is equal to 1.0: the *desired mill capacity* is the same as the current mill capacity. But above or below this level, as profitability increases or decreases, what is the shape and scope of the curve. For example, if profitability is 50% higher what is the likely reaction of mill owners? Increase mill capacity by 10%, 25% or 50%? What if profitability is 50% lower? The model can be used to test the effect of different values for this effect, but it cannot discover the correct one. If the model is not very sensitive to this model component, then the questions are not important. If the model is sensitive to changes in this component, then it needs to be quantified more carefully.

Another function, the *effect of relative profitability on mill operations,* allows us to determine how rapidly the mill might lay off workers or shorten work hours as profitability falls. Or conversely how quickly mill operations will be pressed into overtime if profitability rises.

The third function in this part of the model determines the *effect of demand on purchase price* of logs. This function addresses the question 'how much does the *desired mill log price* change as demand for logs exceeds or falls short of the supply of logs?'

Logging and Log Supply

This segment of the model deals with the relation between logging and log supply and factors which affect the profitability of logging (Figure 3). *Current domestic purchase price* has a direct and substantial effect on the *potential profit from log harvest* which is also affected by *costs of logging*. Log contractors will weigh this potential profit against what they might view as the *normal profitability of logging*. This comparison, the *relative profitability of logging*, will determine whether it is desirable to establish more logging teams to cut trees. Relative profitability also determines whether it is desirable to use existing logging teams to full capacity (*capacity use*) or not. The *capacity use* is then combined with the actual *logging team* capacity to determine the *amount of timber* *cut each year.*[3] Logging teams are always changing and the times for the teams to build up or decrease are also important model components.

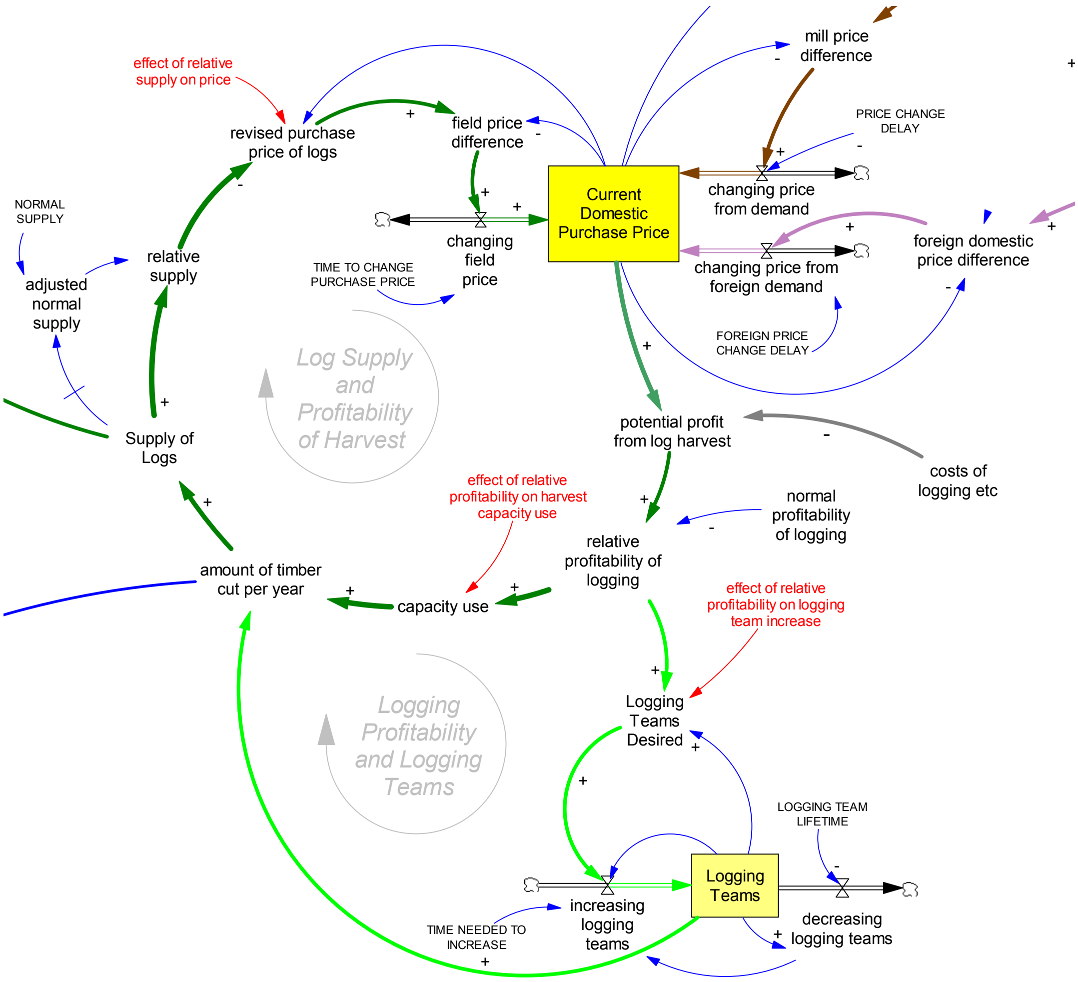

Figure 3. Logging and Log Supply. Model components linking current domestic purchase price to log harvest and harvest capacity (=logging teams). Note that some model components have been removed for clarity.

The amount of timber cut yields a *supply of logs* which, when compared to the *adjusted normal supply* (typical supply in the recent past) provides a measure of *relative supply* which affects the desired, or *revised, purchase price of logs*. This revised purchase price then becomes one of the elements affecting the *current domestic purchase price*.

There are three functions in this segment of the model which are important model components needing careful study. As in the first model segment, two of these are related to the response to profitability on the part of entrepreneurs. What is *the effect of*

[3] Ideally the amount of timber cut would also be limited by allowable cuts and forest management plans, but this does not seem to be a relevant component at present.

relative profitability on harvest capacity use? That is, to what extent are logging teams told to slow down when profits drop. Also, what is the *effect of profitability on logging team increase* when profitability rises or drops. This is particularly important in that once *logging teams* are built up there is a lag before they can drop again. Lags of this sort introduce instabilities into a system.

The third function in this portion of the model is the *effect of relative supply on price* which determines how much of an effect excess or limited log supplies have on the price expected by loggers. This price then becomes one factor in determining the *current domestic purchase price*.

Foreign Demand and Export Price

This sector of the model deals with export demand and price and the direct effects of any export ban. Here *foreign demand for Indonesian logs* is part of a feedback loop linked to the *current export price*. This is similar in structure to the loop seen for domestic demand except that here we have not included effects on foreign milling capacity but have merely given that as a model constant, *basic foreign demand for logs* (Figure 4).

As in the domestic sector demand, *foreign demand for Indonesian logs*, when compared to the supply, *log exports*, yields a *relative export demand* having a value dependent on the balance between exports and demand. The *effect of export demand on export price* is dependent on the *effect of export demand on price function* the formulation of which is critical. If Indonesian logs dominate the market then their removal from it will have a significant effect on price. On the other hand, if there are many other sources of logs then the effect of a decreased supply from Indonesia would be negligible. Whatever this effect of demand on price might be, it acts to adjust the normal export price upward or downward. This *adjusted export price* will gradually be absorbed into the *current export price*.

Just as demand affects export price, the *current export price* can affect demand. Increases or decreases in *current export price* compared to the *normal export price*, will cause an *effect of price on demand* which will affect the *basic foreign demand for logs* creating a *foreign demand adjusted for price*. Depending on the *time needed to change foreign demand* changes this adjusted demand is gradually absorbed into foreign *demand for Indonesian logs*.

Importantly, the *current export price* is also one factor affecting current domestic *purchase price*. This is a major reason why a log export ban is being considered. However the magnitude of this effect may be difficult to determine. If export price was very high, but no logs could be exported then presumably the effect on domestic log price would be minimal. The actual impact of *current export price* on domestic price, is determined in part by *the effect of foreign export volume on price*. If export volume is high then the effect of export price will be high.

Also, the amount of *log exports* must be some function of price as well. At this point we probably do not want to model the decision processes used by entrepreneurs to determine if logs should be sold to a mill or be exported. Instead we can use the *export price ratio* along with the function, *effect of pricing on amount exported*. Clearly this is an important function, the design of which will significantly affect model outcome. It may be, for example, that exports follow a direct relationship with the export price ratio: if export and domestic prices are the same, then half of available logs will be exported. If export prices are three times domestic prices then exports will be three times domestic log sales. On the other hand we may believe that proportion of exports rises more rapidly than the *export price ratio*. For example if export price were three times the domestic price then exports might be 5 times domestic sales. The slope and shape of this curve is rather important and various formulations will need to be investigated.

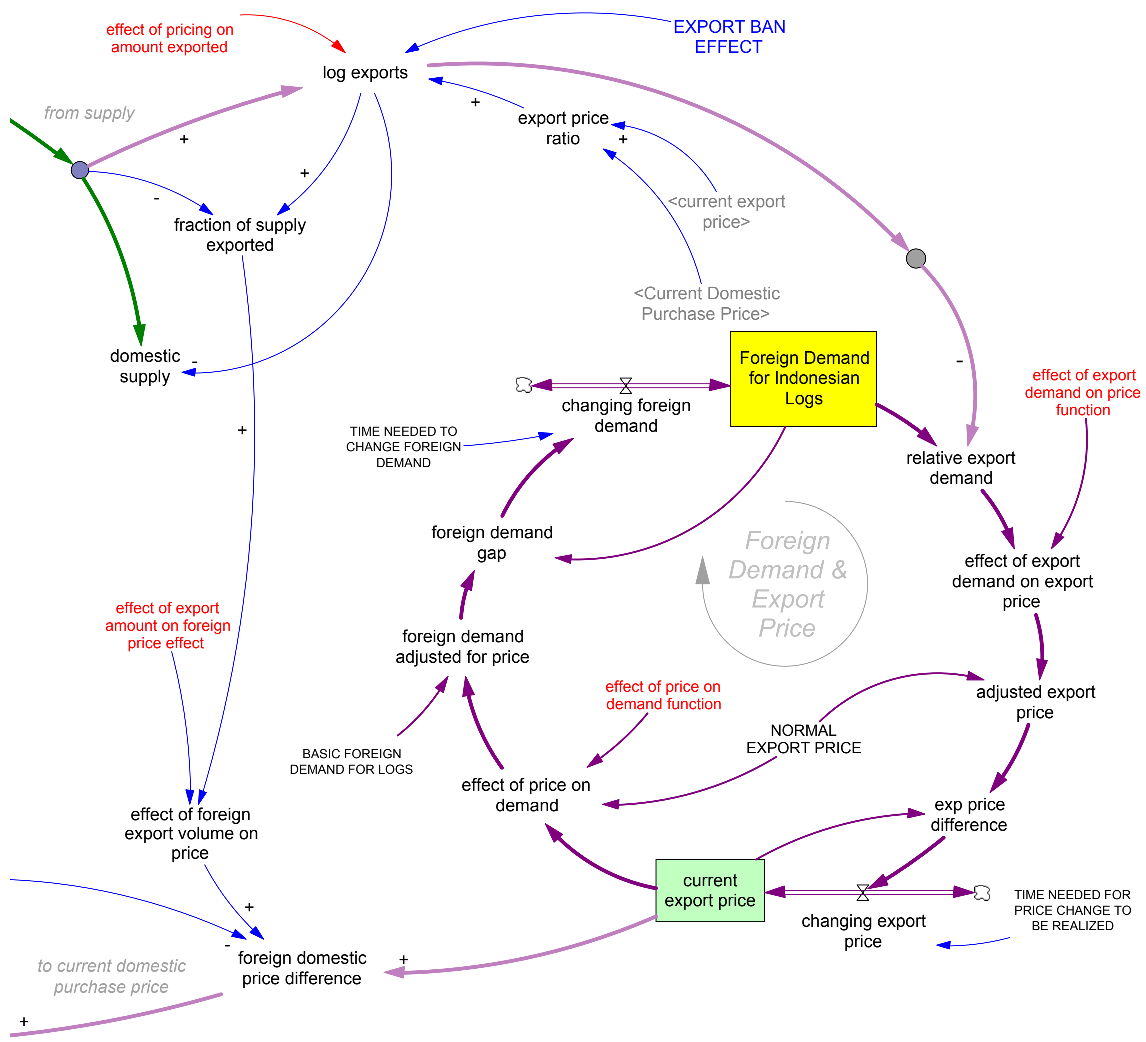

Figure 4. The portion of the model used to determine export demand, export price and amount of exports. Note that other model components have been removed for clarity.

Effect of Harvest on Forest

The final model sector is that dealing with the effect of log harvest on the forest. This very simple representation of a forest is based on an average ha of land within a 1 million ha forest (although any amount of forest could be used). The forest on this average hectare is represented by *m^3 currently on each ha of forest land*. This amount can be changed by *harvesting* and by *regeneration*, which combines creation of new trees, growth and deaths of trees. Regeneration is dependent on the stock volume already on the land and on the ratio between it and the *maximum standing stock* because there is an *effect of stock ratio on regeneration*. As the forest becomes more densely stocked the *regeneration* approaches zero.

In this model formulation *m^3 currently on each ha of forest land* is equivalent to the *availability of trees for harvest*. Under an ideal forest management system the *availability of trees for harvest* would also be limited by forest management plans. Herein it is assumed that the only feedback from the forest to the remainder of the model is the probable effect on logging costs of the relative *availability of trees for harvest*. It is assumed that as trees become more scarce logging costs rise. This is not necessarily the case, since some harvesting may make access to the forest easier thereby lowering logging costs. It may also be the case, under the current situation, that average logging costs are not yet affected by forest availability.

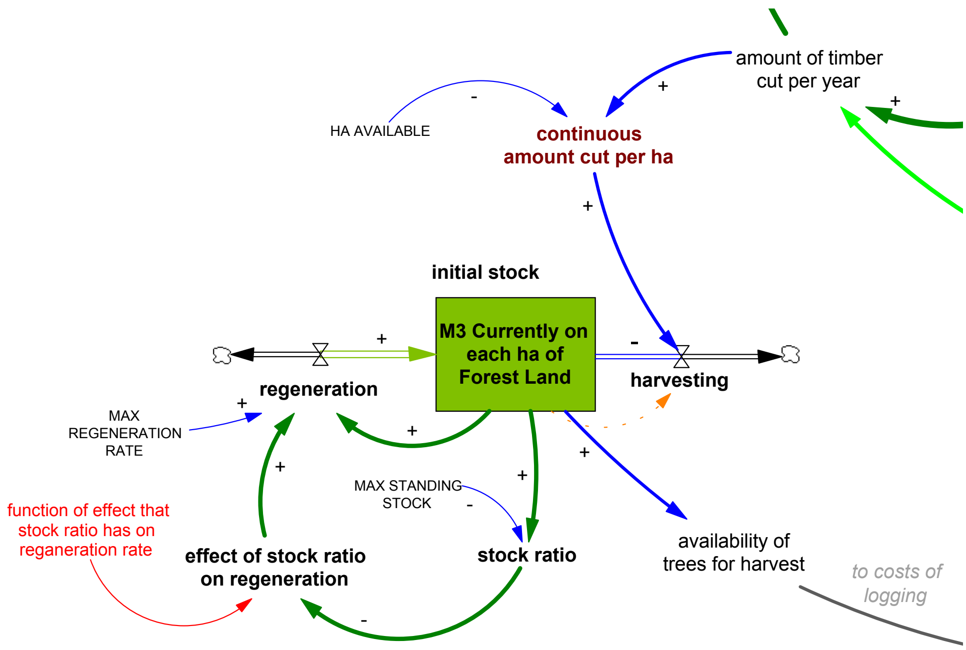

Figure 5. Model components used to determine forest cover, forest regeneration and harvest effects on forest. An arbitrary area of 1 million ha with maximum sustainable harvest of 3m^3 per ha per year has been used. Note that other model components have been removed for clarity.

Model Outcomes

Effect of Gradually Increasing Foreign Demand

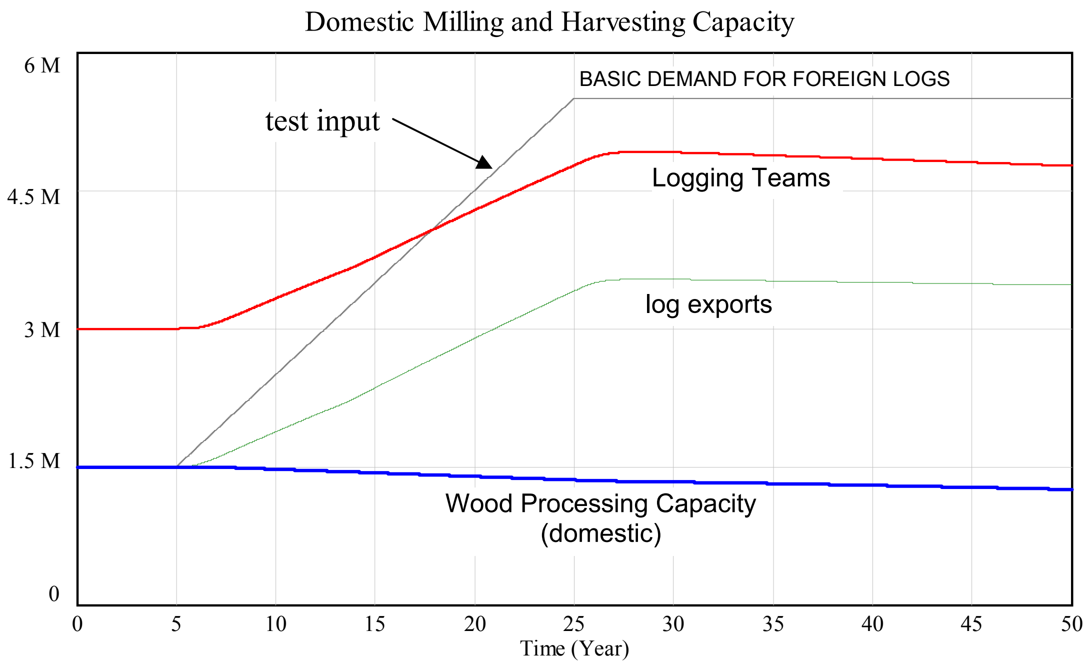

Figure 6. Response of milling and harvesting capacity to increasing foreign demand. As log exports rise in response to increasing foreign demand, logging teams increase substantially and domestic milling capacity drops slightly.

Here the model is used to examine the effect of a gradual increasing foreign demand for Indonesian logs. An increase of 200,000 m^3/year for 20 years starting in year 5 is tested. Following the 20 year period foreign demand remains constant. The model starts with foreign and domestic demand each at 1.5 million m^3/year. After the 20 years basic foreign demand has risen to 5.5 million m^3/year(Figure 6).

As *foreign demand for Indonesian logs* increases, *log exports* increase as expected. Increasing log prices (see Figure 7) stimulate creation of more logging teams providing the increased harvest. As domestic price increases domestic *wood processing capacity* declines because higher prices limit profitability.

As export demand increases the *current export price* also increases causing an increase in *current domestic purchase price*. Downward pressures on the domestic purchase price are caused by dropping *desired mill price* and by increasing log supply due to increasing production by the logging teams (Figure 6). Thus prices increase enough to encourage more cutting and to discourage domestic milling, but not enough to limit exports.

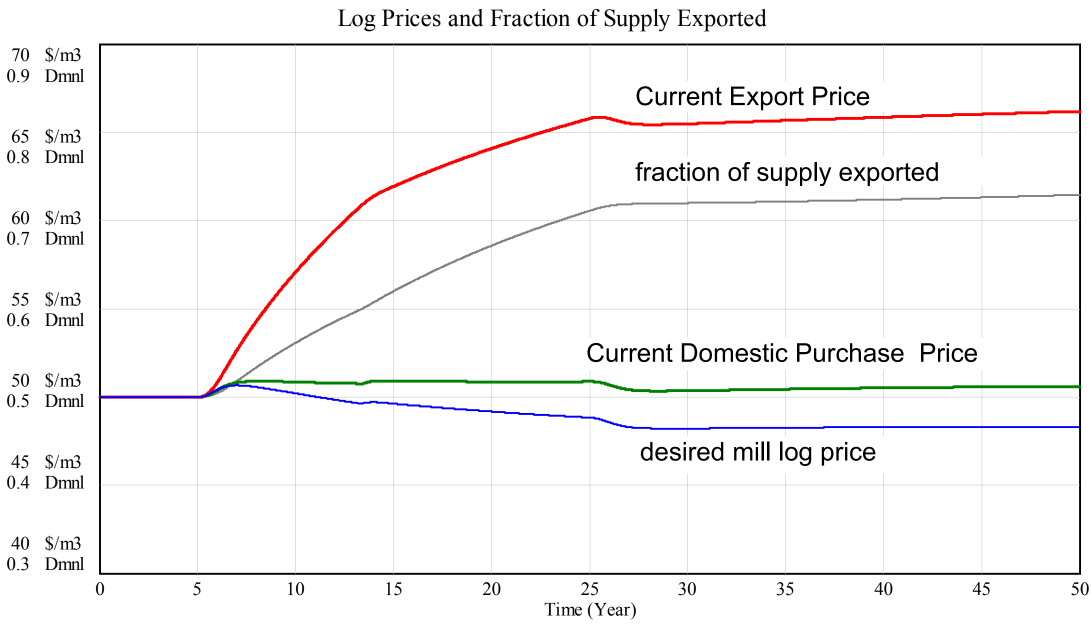

Figure 7. Effect of increasing foreign demand on prices and the fraction of supply exported.

Application of a Log Export Ban for Five Years

A second test of the model involves the implementation of a 99% effective log export ban for five years. Immediately after the ban is instituted *log exports* drop and *current export price* starts to rise but has little effect on domestic prices.[4] Logging team harvest capacity decreases due to a significant decrease in demand even though domestic wood processing capacity rises slightly (Figure 8).

When the log ban is lifted in year 25, log exports jump quickly to their pre-ban level, drop back and then jump to a higher peak prior to stabilizing at the pre-ban export level. Logging teams respond to the increasing demand, but because of increased current domestic log price, and associated profitability of logging, logging team capacity overshoots the supply and after about two years stabilizes at the pre-ban harvest capacity (Figure 8 and Figure 9).

Figure 10 shows more detail shortly after the lifting of an export ban. Because of the lingering high export price, most logs available in the reduced supply are exported. This drives up domestic prices which pushes exports down, and also stimulates log production. Both export and domestic prices drop as supplies increase. In this simulation, export price declines more slowly than domestic price causing a stimulation of exports. Three

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[4] Note that I have assumed a significant effect of Indonesian log supply on foreign price. With no logs exported the current export price triples from 50 to 150 $\$/m^3$.

years after the ban the system has returned to its pre-ban values with the following exception: *domestic wood processing capacity* is about 0.5% higher than pre ban values causing log harvesting to be slightly higher as well.

System behavior during the immediate post-ban period is dependent on the lag times used in the stocks (e.g. *time needed for price change to be realized*). Since we don't know these lag times exactly, events during this short period should be viewed as an example of the types of interactions that are occurring rather than an exact representation of outcomes.

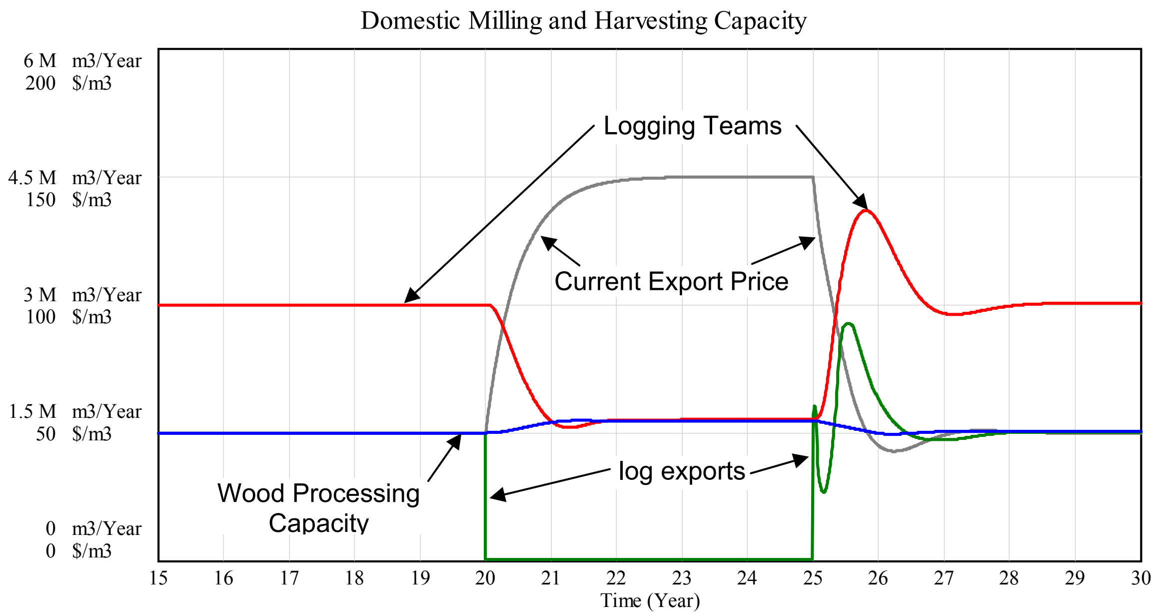

Figure 8. Effect of a log export ban (year 20 to 25) on wood processing and harvesting capacity.

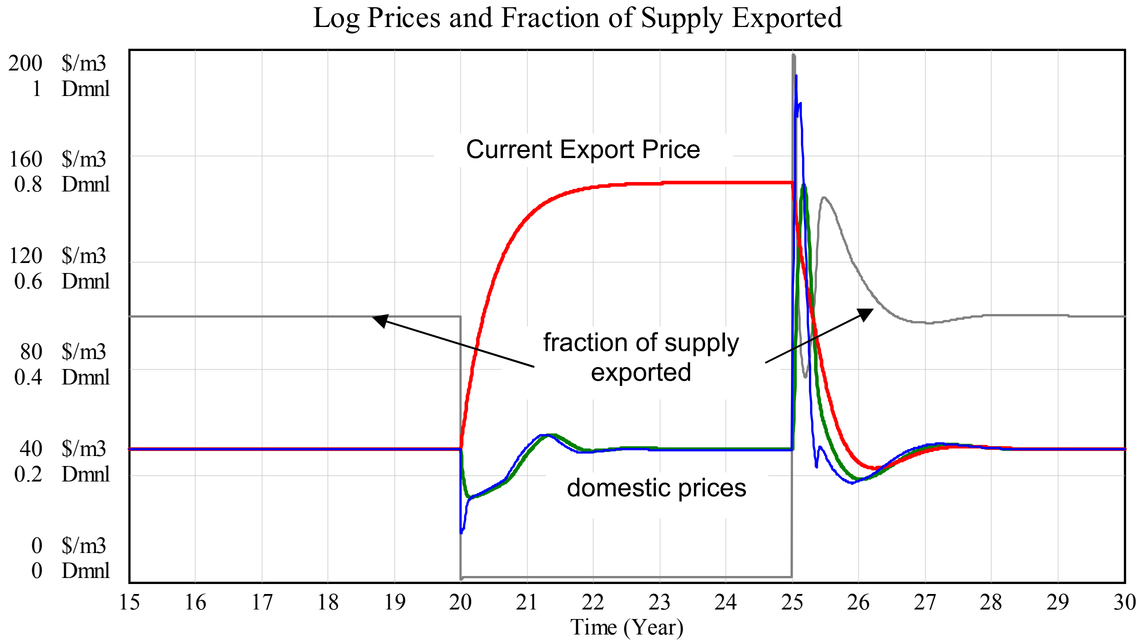

Figure 9. When a log export ban is instituted export prices rise but have little effect on domestic prices which fall due to a sudden increase in supply. As supply drops domestic prices rise to their previous level. See next figure for detail of year 24 to 27 when the export ban is lifted. "Domestic prices" in this figure refers to *current domestic purchase price* and *desired mill log price*.

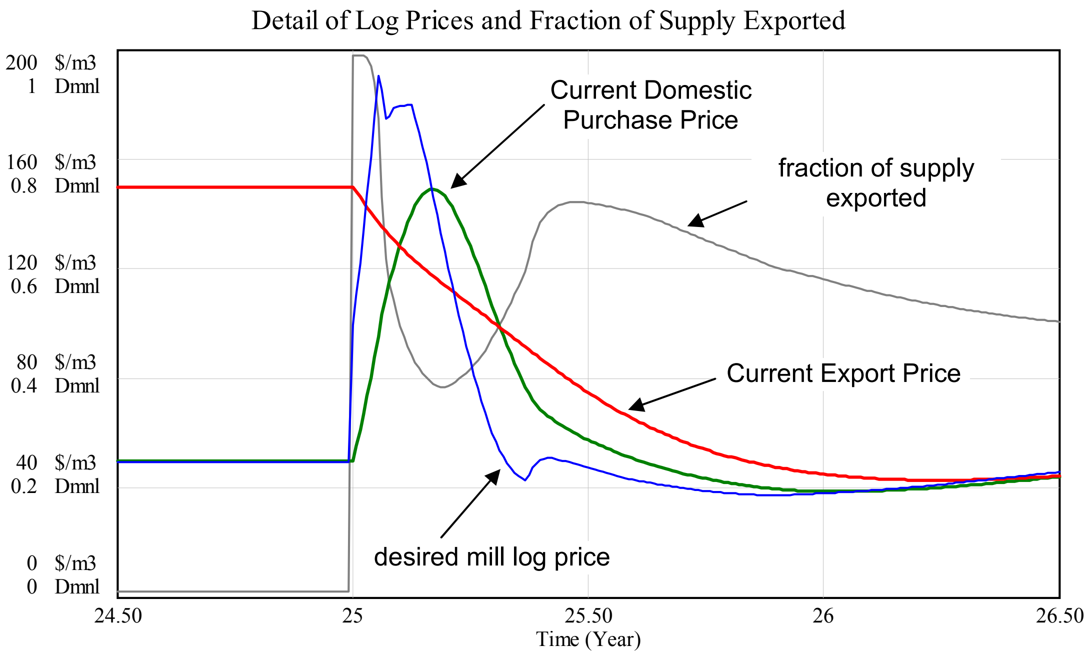

Figure 10. Detail of removal of a log export ban (in year 25). Immediate effect of dropping the ban is an export of most available logs driving up the domestic prices. This causes a drop in exports, but as log production is stimulated by higher current domestic purchase price exports climb again.

Increasing Foreign Demand and a Log Export Ban

Indonesia has been exporting an increasing amount of logs, so if a log export ban was to be introduced it might be considered to occur in conjunction with rising foreign demand.[5] The third example will look at this situation, combining the two tests above.

Figure 11 illustrates the situation with increasing foreign demand (from year 5 to 25) interrupted by a log export ban from years 15 to 20. For the most part details are similar to the previous example (see Figure 10). In spite of the export ban the general trend of increasing foreign demand and its effects on prices and exports continues after the ban is lifted.

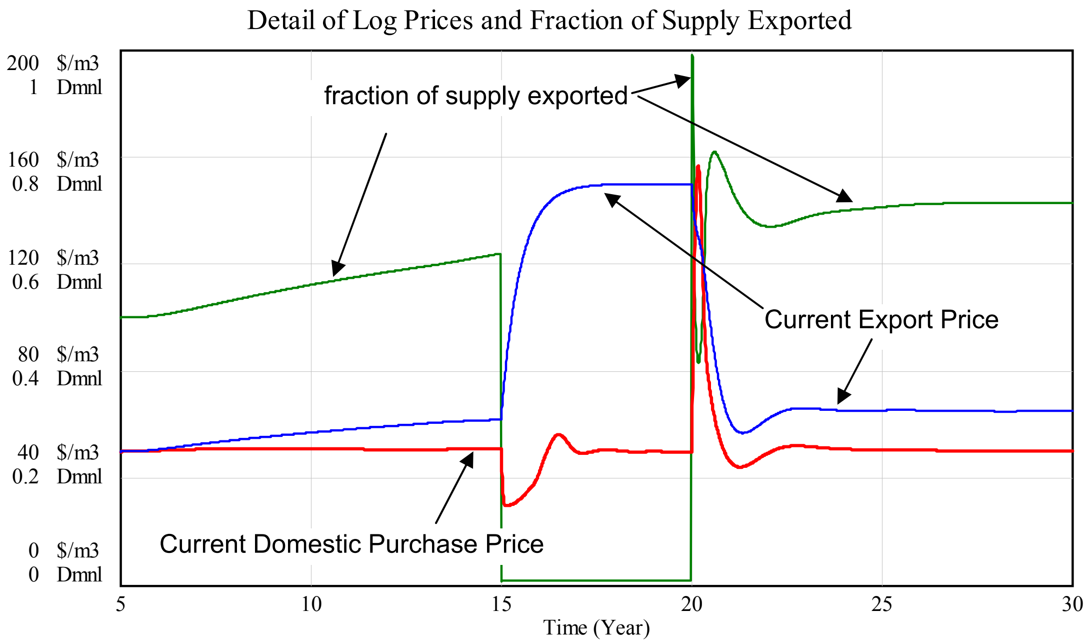

Figure 11. Domestic and export prices and the fraction of logs exported under a gradually increasing foreign demand interrupted by an export ban.

Harvest capacity drops significantly during the log export ban but quickly responds in response to foreign demand when the ban is lifted. Forest cover starts to increase during the ban, but once the ban is removed forest cover resumes its decline Figure 12. *Domestic wood processing capacity* and associated *domestic demand for logs* both increase during a log export ban, but resume their decline after the ban is lifted though at a slightly higher level (Figure 13).

[5] Assuming that increasing exports are due to increasing demand.

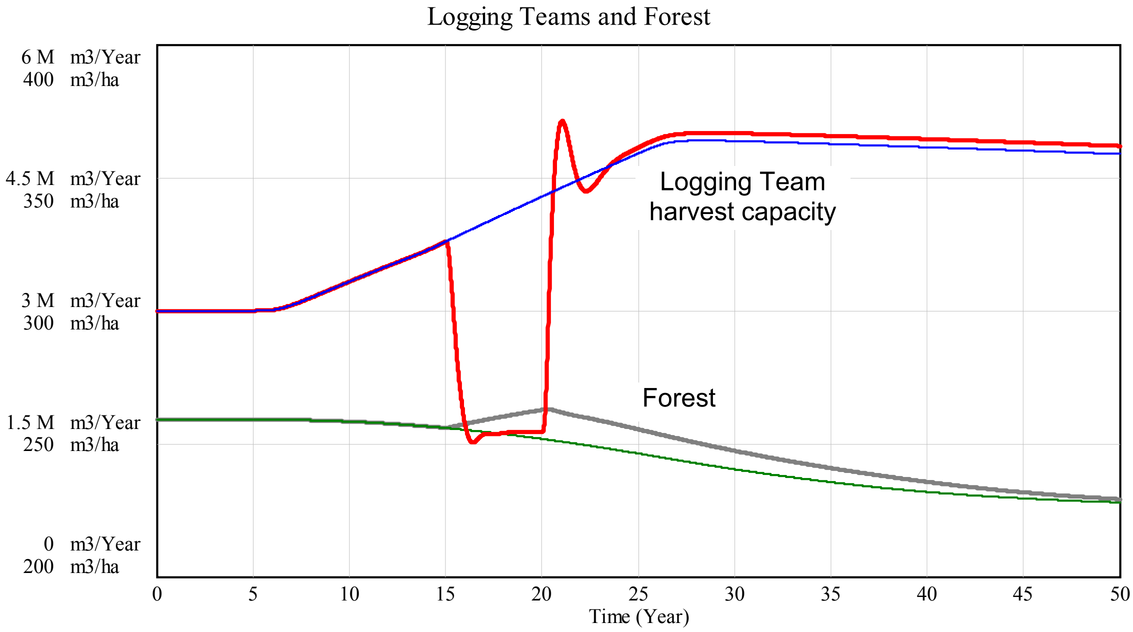

Figure 12. Effect of a log export ban on harvesting capacity and forest cover during a period of increasing foreign demand. Results with, and without, the ban during years 15 to 20 are shown.

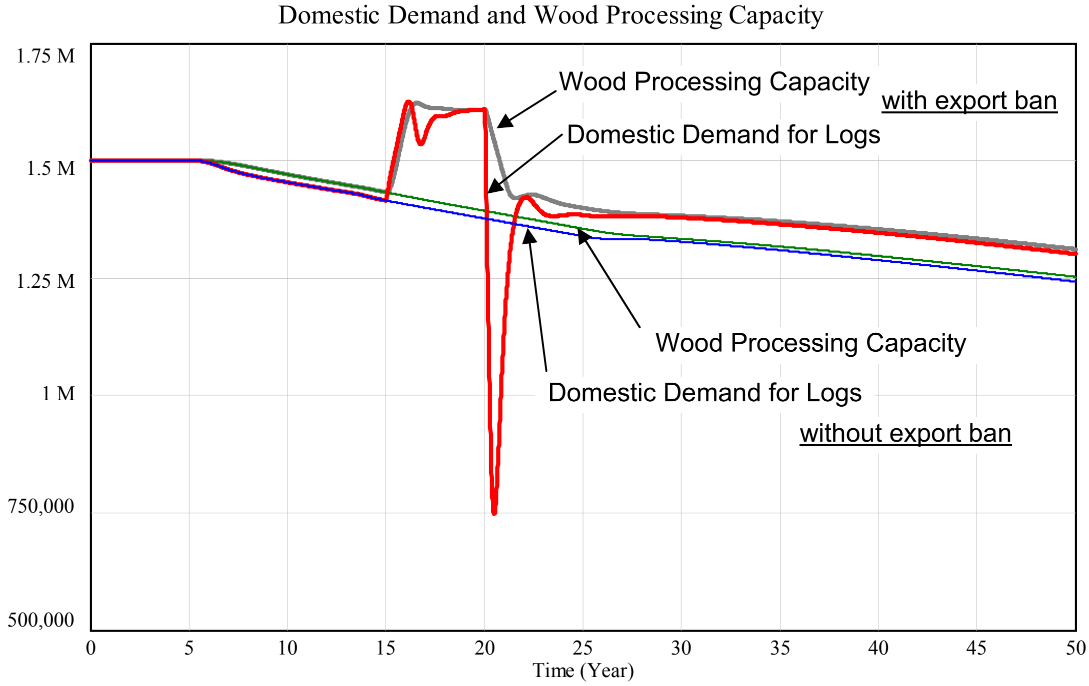

Figure 13. Effect of a log ban on domestic use of logs. An export ban causes a temporary jump in domestic demand and processing capacity. Following removal of the ban both demand and capacity remain somewhat higher than without the ban, although both continue to decline.

Effect of Variations in Domestic Milling Investment Response

More aggressive responses to profit opportunities might alter the outcome of the above scenarios. For example, what if mill owners aggressively expanded their operations during periods when profitability was high and severely limited mill expansion when profitability dropped.[6] This test examines that question by using four relationships presented in Figure 14.

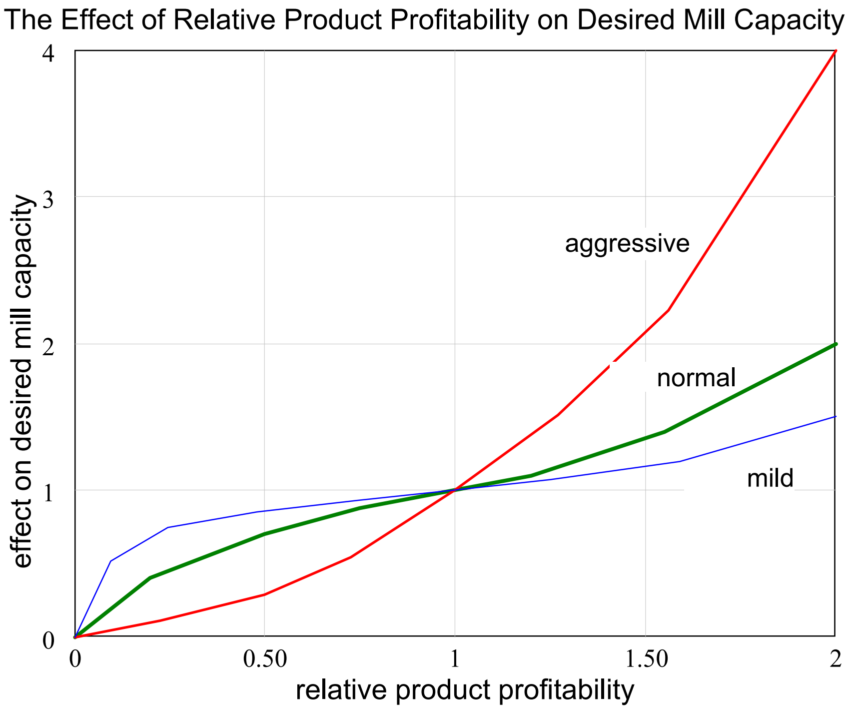

Figure 14. Functions used to examine the effect of different responses to changing wood product profitability. For example, with the aggressive response mill owners would be more likely to invest in new mill capacity if the profitability increases. Specifically if profitability is twice its normal value then, with the aggressive strategy, mill owners would desire a quadrupled mill capacity, other things being equal (see the pertinent part of the model in Figure 2). A fourth relationship, the aggressive and hold strategy, incorporates the right-hand portion of "aggressive" and the left hand portion of "mild."

The outcomes reveal that some while some "mill investment strategies" make only minor differences to the effects of the log ban plus increasing foreign demand scenario discussed in the previous example, other strategies can cause major differences in the outcome. For example, the maximum difference between the aggressive and mild

[6] When I refer to the behavior of mill owners I am referring to the average behavior of many mill owners not the behavior of a single owner. In other words, we are interested in the effect that the overall behavior of mill owners has on the system.

strategy, which occurs during and shortly after the log ban, is between 10 and 12 percent of total domestic log demand (Figure 15).

A fourth strategy, called "aggressive and hold", has a much more significant effect. This strategy is identical to the "aggressive" strategy to the right and identical to the "mild" strategy to the left of Figure 14. It implies aggressive accumulation of processing capacity at times when profitability is high, plus a tendency to hold on to that capacity when profitability drops below normal.

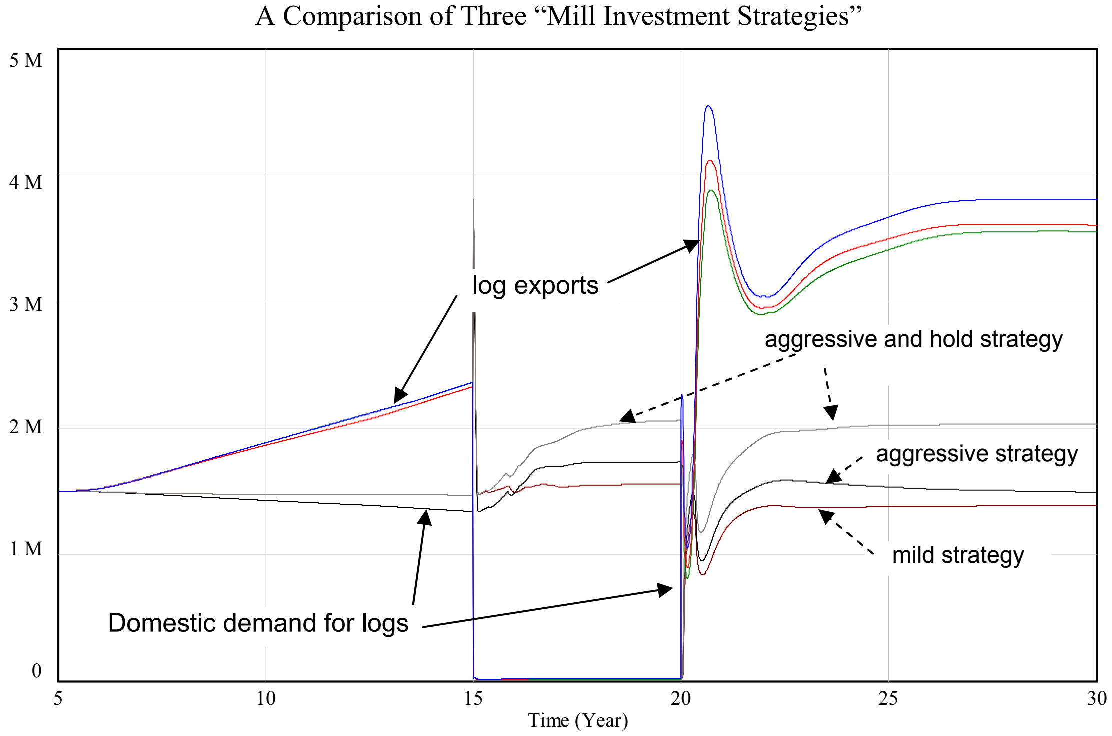

Figure 15. Log exports and domestic demand for logs under three different mill investment strategies. Different strategies can affect the overall outcome over time. For example the "aggressive and hold" strategy produces significantly higher domestic milling capacity during and after the log ban.

With this "aggressive and hold" mill investment strategy, domestic log demand jumps during the log ban and does not disappear when the log ban is lifted (Figure 15). This leads to a 33% increase in domestic capacity after removal of the ban (Figure 17).

This strategy also has a significant effect on forest cover as portrayed in Figure 16. The accumulation of domestic processing capacity causes a more rapid decline in forest cover than under the alternate strategies examined.

While these strategies are merely rough examples of what could happen under different scenarios, they do reveal that there is no guarantee that a temporary log ban will reduce pressure on forest by lowering overall demand. The outcome is dependent, at least in part, on the response of domestic mill owners to temporary increases in log supply and decreases in domestic log price.

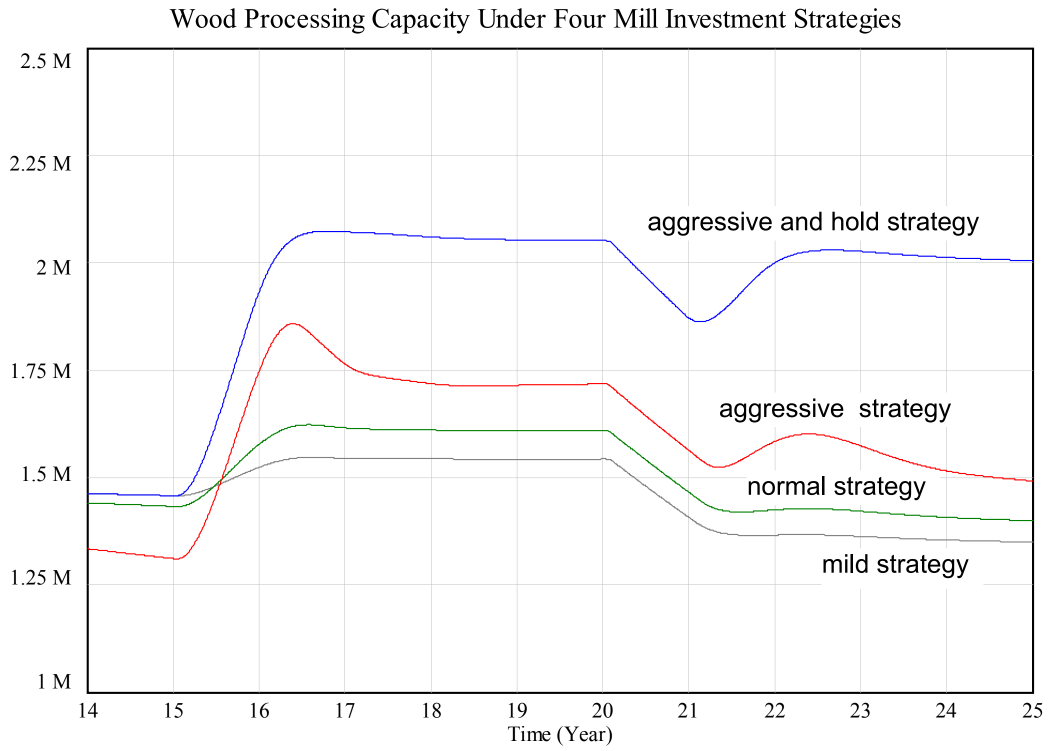

Figure 17. Domestic wood processing capacity under three investment strategies during and shortly after a log ban in years 15 to 20.

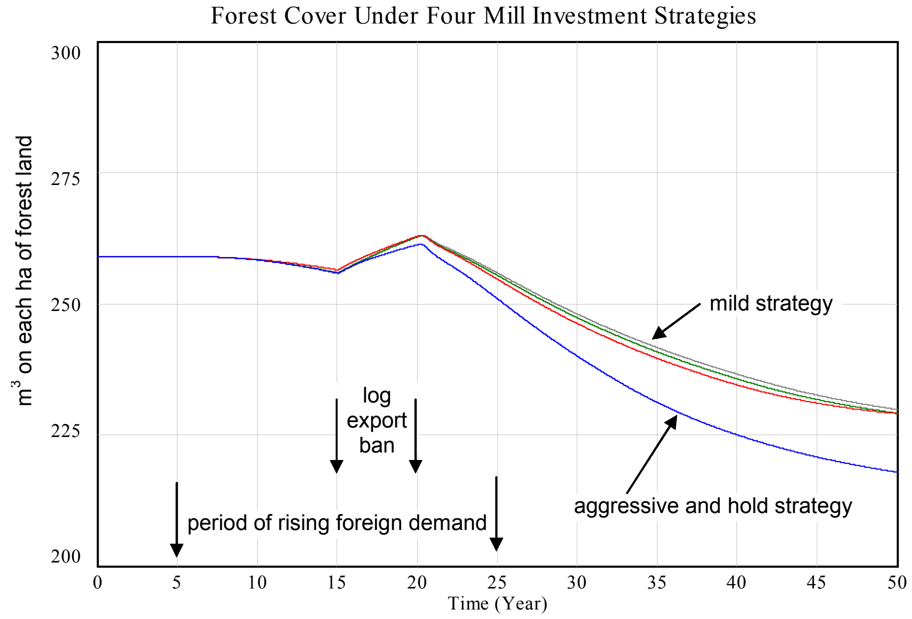

Figure 16. Effect of four mill investment strategies on forest cover during a period of increasing foreign demand interrupted by a log export ban.

Changes in Export Price

In the previous discussions export price was permitted to rise to as much as three times the normal export price in response to increases in foreign demand resulting from a shortage of supply during a log export ban. However, a lower maximum price may be more realistic. Figure 18 indicates three of many possible responses of export price to changes in export demand.

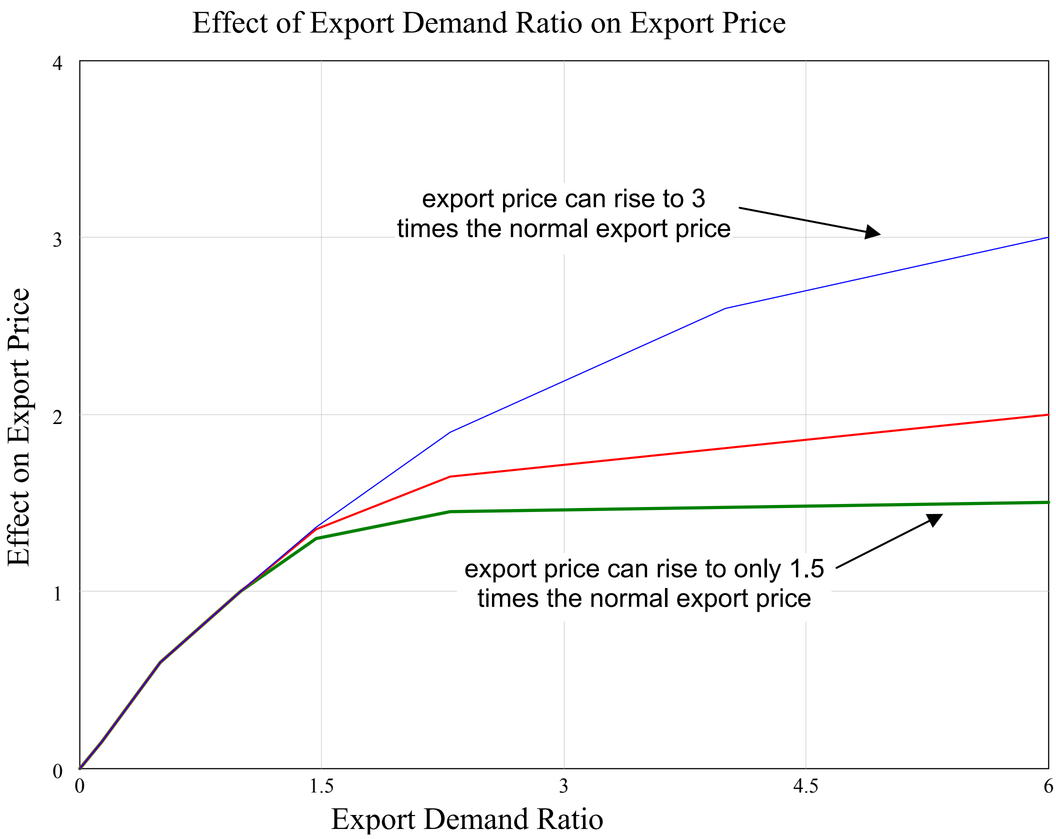

Figure 18. Three possible relationships for the effect of the export demand ratio on export price. At the point (1.0, 1.0) there is no effect. As export demand rises export price will rise but will approach some maximum

During a log export ban export prices rise because the ban restricts the satisfaction of export demand. During the ban increasing export prices have little effect on other parts of the system. If logs cannot be exported the rise in price in meaningless. However, there is a lingering effect of these high prices when the ban is lifted and this lingering effect causes interesting dynamics in the system (see, for example Figure 10). This lingering effect is more pronounced if export prices rise higher during the export ban. The example in Figure 19 illustrates the different responses of *amount of timber harvested* using the different relationships shown in Figure 18.

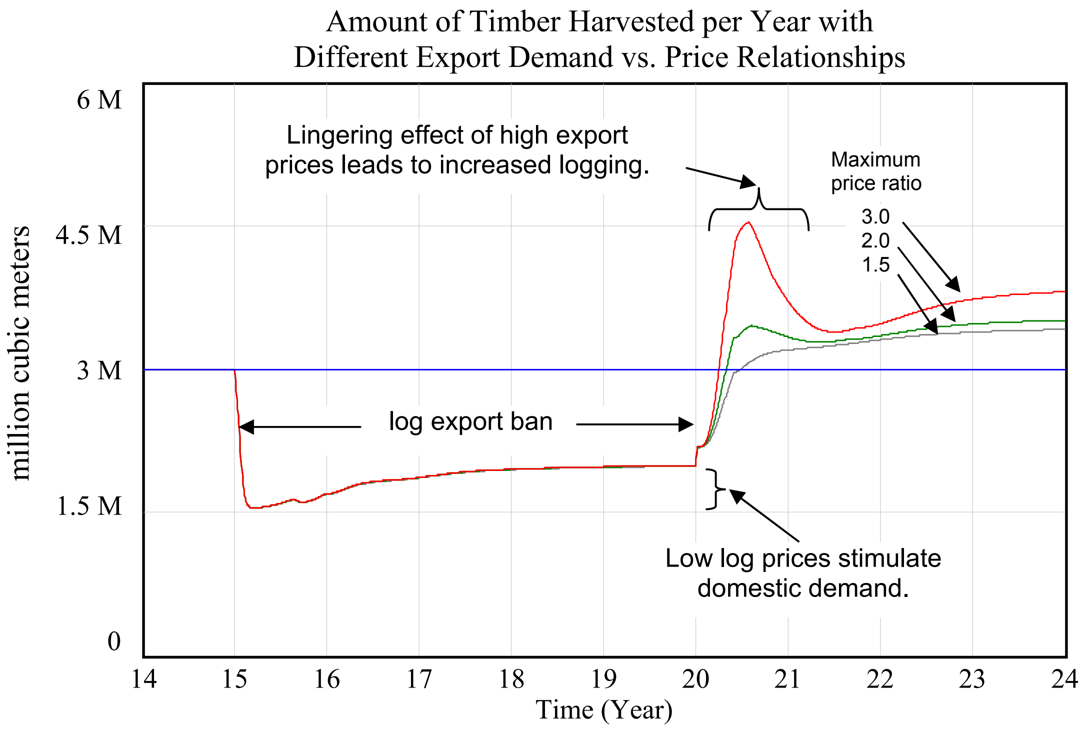

Figure 19. An example of how different export demand vs. price functions can change the effects of a log export ban. Here the amount of timber harvested is shown for the three different demand vs. price functions shown in Figure 18. If export price rises more during an export ban the lingering effect is more pronounced.

The Question of Illegal Logging

A full examination of illegal logging requires a different model designed to examine a range of social, economic, legal and political issues. Nevertheless, a few of these issues can be examined by making minor modifications to the model presented here. One of these modifications is based on the fact that illegal logging lowers the costs of harvesting logs. This raises profits of logging operations, stimulating the harvest of more logs, lowering the price of logs which makes wood processing and log exports more profitable as well. Thus, one simple examination of the response of the system to illegal logging can be tested by lowering logging costs.[7]

For example, we can assume that illegal logging lowers logging costs by between 5% and 20% over a five year period (Figure 20). As logging costs decrease below normal, logging allows windfall profits to be made. Consequently logging continues to increase unless something limits these profits. Although an increasing supply of logs will tend to

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[7] Within this section, for simplicity, the model has been used with only the aggressive and hold strategy of mill investment (see Figure 14) and only allows the export price to reach 1.5 times the normal export price (see Figure 18).

lower log prices, the lower log prices will stimulate new processing capacity which will absorb the increased log production allowing logging to increase further. Only when supply of trees become limited does the harvest decrease.

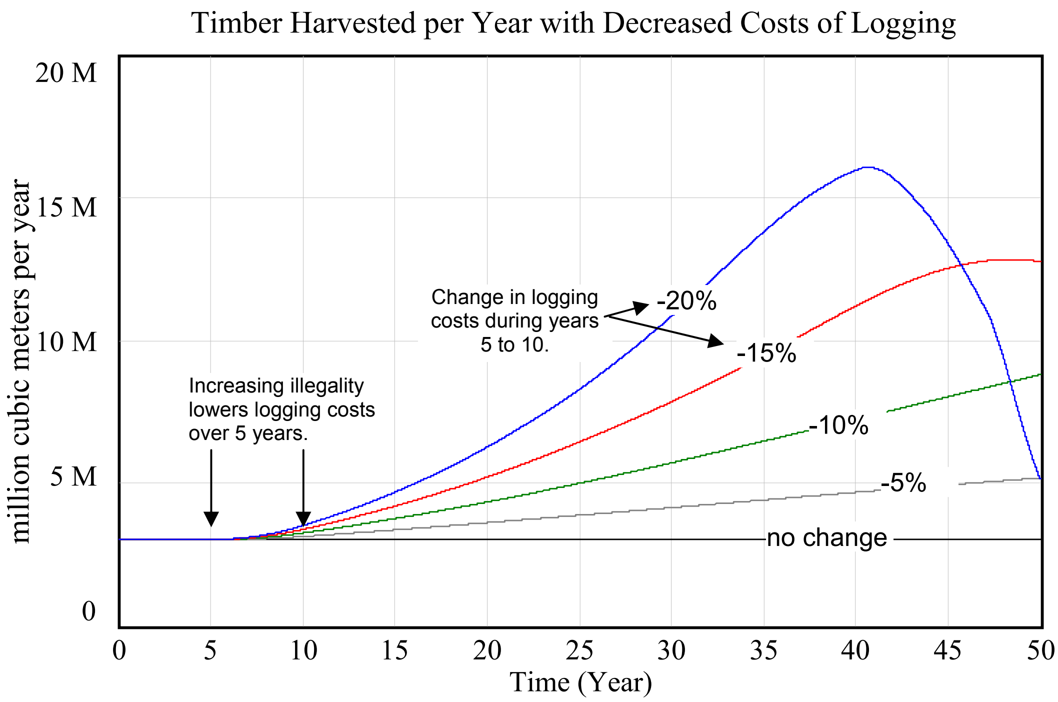

Figure 20. Predicted timber harvests under situations where logging costs have decreased by various percentages over an initial five year period. Decreased logging costs allows windfall profits which stimulates logging lowering log prices stimulating further demand for logs. Eventually scarcity of logs cause logging costs to rise. While it is assumed here that illegality lowers the costs, other factors could have the same effect.

Having seen the effects of lowering logging costs in Figure 20 various scenarios to control this effect can be examined: no action, a log export ban, re-control which raises the logging price to normal, and a log export ban plus re-control (Figure 21).

A reduction of logging costs to 80% of their normal value causes a rapid rise in logging until costs of logging are limited by availability of logs. A log ban does not control this trend and merely stimulates a higher level of logging and a more rapid collapse. The reason for this is that the profitability of logging does not change significantly until limited log availability raises costs. If logging costs are re-established at their original value (in year 17.5) logging levels are controlled and slowly drop. A logging ban makes such re-control less effective. Note that the nature of the relationship between tree availability and logging costs (which causes the crash) is only roughly estimated. It seems likely that a crash would occur sooner than indicated here.

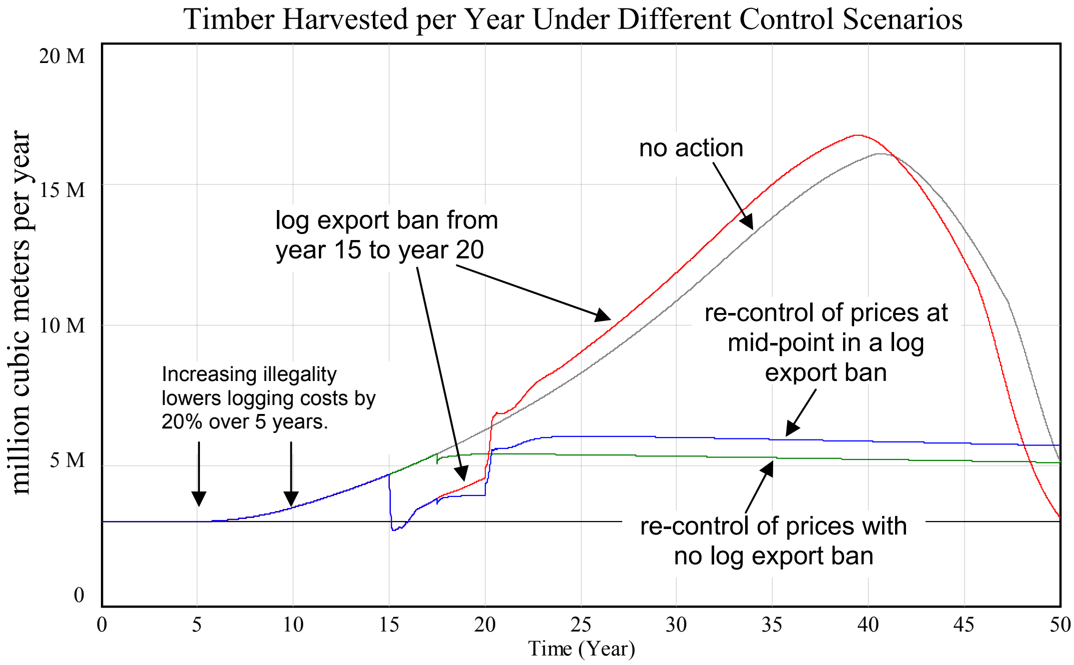

Figure 21. Possible scenarios for regaining control of logging following a drop in logging costs due to illegal logging. Under the conditions modeled, a five year ban on log exports actually stimulates more logging. Re-control to reestablish original logging price stabilizes the amount of logging, but does not return it to the original value. Recall that the outcomes are highly dependent on the values used for mill investment strategies and for foreign price rise during an export ban (see text).

Discussion

System dynamics modeling provides an excellent framework for looking at the possible outcomes of a log export ban. This approach allows us to examine the interlinked relationships between demand and price, harvesting capacity, milling capacity and other factors. The critical question that arises when examining this system is how to accurately formulate the relationships between various model components. What we believe to be correct relationships have been presented in this paper. However, the exact nature of these relationships is not accurately known. This modeling approach allows us to look at several formulations of these relationships and allows us to examine the outcomes of each. Following such an examination we could follow-up with the collection of additional data related to relationships that are deemed most important based on the model.

Although the model presented here is preliminary, it does give indications as to where questions remain in examining the benefits and costs of using a log export ban. It also provides reasonable information about the utility of an export ban plus some more general findings related to attempts to control illegal logging with an export ban.

For example, the model indicates that different responses by mill owners to changes in log prices can result in very different outcomes, in some cases making a temporary log ban less beneficial for forest protection than no ban. Importantly some policymakers supporting the ban believe that it will help the local log processing industry by lowering log prices thus allowing expansion of domestic milling capacity. If this view is correct, then the other rationale for having a log ban, prevention of over-harvest, may not be valid. That is, if local processing capacity increases significantly due to lower prices caused by a log ban, then the effect of the log ban on protecting forest cover will be less. Consequently, the expected response of mill owners to any log export ban should be examined carefully, as should any government policies which might stimulate mill investment.

Some other areas where additional information is needed are as follows:

> How much will export prices change when Indonesian logs are removed from the export market? In other words, to what is the effect of the supply to demand ratio on the export log price (which in the model is represented in the component, *effect of export demand on price function*)? If this function is different from those used in the model, how will model outcome be affected?
>
> There is also the question of how entrepreneurs might respond to changing profitability of logging (represented in the model component, *effect of relative profitability on logging teams increase*). How quickly will logging teams decrease if log prices and logging profitability drop? Will people making up the logging teams continue to cut trees anyway in order to make a living. Will this actually increase the amount of trees cut has price drops in order to maintain their income level? If so, how would this affect log prices and demand?

The model, as presented here, reflects the real situation, not the ideal situation. As presented there is no feedback whereby decreasing availability of trees for harvest directly limits amount of timber cut per year. This feedback occurs only via a decrease in logging profitability. If various factors conspire to maintain logging profitability in the face of decreasing forest cover, the forest will be over-harvested. This is the sad reality of Indonesia's forest industry.

Examining Model Validity

Background

A system dynamics model should produce the *right results for the right reasons* (Barlas 1996, Coyle 1996). The structure of the model should mirror the real system to the level of detail needed for its purpose. A system dynamics model can be viewed as a *theory of how a system works*. This means that model validity is connected to our view of how theories are justified. For the most part system dynamics practitioners do not view models as either true or false, but view them as one of many possible representations of reality (for further discussion see Barlas 1996). As a simplification of reality, a model will not be identical to the system being modeled, but in general must be *good enough for the purpose intended*. Its usefulness for a specific task, rather than absolute accuracy, is what is important.

Coyle and Exelby (2000) refer to two aspects of model validation:

> "*Validation*, means ensuring that the model's structure and assumptions meet the purpose for which it is intended. … *verification*, means ensuring that its equations are technically correct"

The first aspect of this is the most difficult, and various approaches for validating models have been put forward (e.g. see Forrester 1961, Barlas 1996, Coyle 2000).

System dynamics models are "white box models" the workings of which should be understandable to *interested clients*: people who wish to use the model and have an interest in doing so. Validation then becomes a process of building confidence in the usefulness of the model in cooperation with these clients. Since such models should be built in conjunction with the clients in the first place, validation becomes, in part, an iterative process of reviewing with the client the model and needed changes, based on preliminary model outcomes, model diagrams and logic, using approaches such as those presented in Forrester (1961) and Barlas (1996). Interested clients are likely to be people who needed the modeling work in the first place, for example, business clients who have contracted model building to help solve a specific problem.

One of the problems with public policy models, such as this log export ban model, is that the intended clients may not be interested. These *reluctant clients* are people who should be interested in the model but are either not interested, or are not aware of it, for various reasons. Validation of models with reluctant clients is somewhat more difficult because it also involves selling the model, and perhaps the idea of modeling, rather than working together to build a useful model.

One reason this situation arises is that public policy makers are usually different individuals from the system "domain experts" who were consulted during the model building process. Policy makers typically have many other issues vying for their attention. In building the log export ban model, expert information was obtained from people studying various aspects of the forest industry (especially illegal logging), not from policy makers *per se*. In this case validation with the domain experts does not actually involve the ultimate client.

Public policy modeling perhaps falls somewhere in between academic modeling and commercial modeling which have different goals and validation concerns (Coyle and Exelby 2000). Unlike commercial modeling, public policy modeling does not necessarily have contractual obligations and associated risks. Nevertheless there are risks associated with making specific policy recommendations, and these risks are greater than those associated with academic (e.g. journal article) reporting of possible outcomes under different scenarios.

Validation Status - Log Export Ban Model

The model described in this paper is in the beginning stages of the validation process. Information for the model structure was obtained from discussions with a number of people working in various aspects of forestry research, industry, and from several environmental non-governmental organizations interested in forestry issues. Initial model ideas were reviewed with some of these domain experts, and these discussions resulted in revisions to the model. The model is verified in that all components have relevant units of measurement and these are consistent throughout the model calculations.

This model has not been validated in detail and several validation steps remain. Most importantly, the model includes a number of graphical relationships describing the effect of one model component on another, but these are based on only a general knowledge of these relationships. Each of these functions should be examined and modified as necessary in cooperation with appropriate domain experts. Similarly, time lags also need reexamination.

The structure of the model appears to be suitable for the task at hand: examining the effects of a log export ban with some limited aspects of illegal logging. However, there may be several components not currently part of the model which additional examination and discussion with domain experts may reveal.

The model as it is currently presented is a good starting point for discussion of a log export ban and its effects on the wood processing and logging industries. This was its original purpose. At present it cannot be used to examine exact outcomes because, as indicated in the previous sections, use of different values in several functions alter the outcome of the model significantly. Thus at a minimum, better knowledge of these functions is necessary before the model could be used for more detailed analysis. If the model is to be used for detailed analysis it should also be validated in a more rigorous manner.

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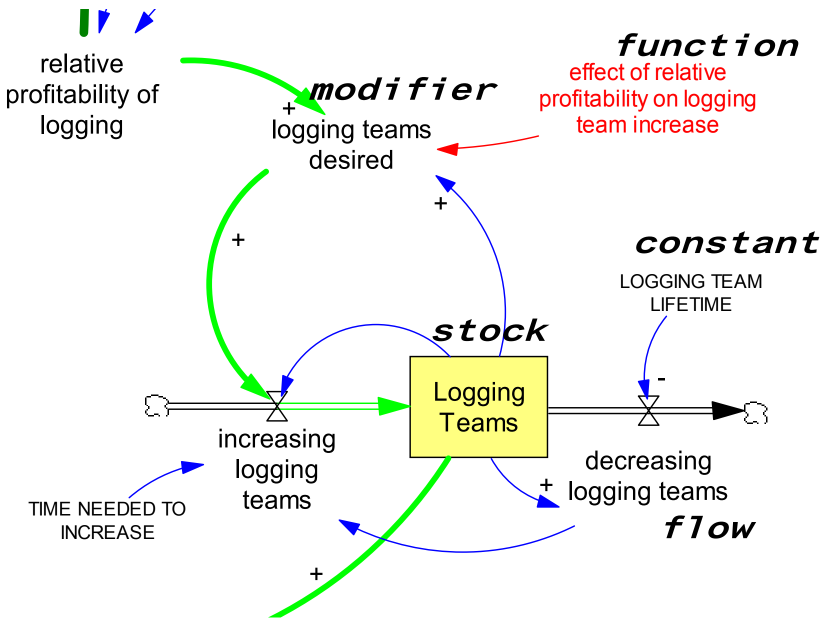
Appendix 1: Modeling Conventions

Throughout the model the following conventions have been used. Connecting arrows are labeled with a plus or a minus to indicate the direction of change of a variable as its predecessor changes. A plus sign (+) indicates that the direction of change is the same – if the first variable goes up the second will go up. A minus sign indicates that the direction of change is opposite (other things being equal). This convention is merely a convenience to aid in understanding the model. Each variable has an equation associated with it which gives the actual method of calculation.

There are five types of model components: Stocks, flows, auxiliary, constants and functions.

> Stocks, also referred to as “state variables” or “levels”, are accumulations over time. They have a lingering effect over time. These are normally presented in boxes and are capitalized.
>
> Flows change the value of stocks over time. These are usually identified by special pipe-like arrows and by the fact that they flow into and out of stocks.
>
> Auxiliary variables are model components that are calculated at an instant in time. These are presented entirely in lower case.
>
> Constants are modifiers that are not affected by other model components. They are given values. These are presented in upper case.
>
> Functions are mathematical, graphical or table-defined relationships between two components of the model. These are lower case but have no arrow pointing to them. I have usually started these names with “effect of ….”. In color figures these are red.



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