

An Application of System Dynamics Modeling
to

The Question of a Log Export Ban
for Indonesia
with Comments on Illegal Logging

- (001) adjusted demand=
demand from mills*effect of product profitability on actual mill use of logs
Units: m3/Year
Current demand for logs by mills as modified by other factors
- (002) adjusted export price=
NORMAL EXPORT PRICE*effect of export demand on export price
Units: \$/m3
Export price after adjustment for changes in demand
- (003) adjusted normal supply=
SMOOTH(Supply of Logs, 5, NORMAL SUPPLY)
Units: m3/Year
Typical supply levels over the past few years
- (004) amount of timber cut per year=
Logging Teams*capacity use
Units: m3/Year
The amount of timber cut each year is dependent on both the logging capacity (logging teams) and on the fraction of that capacity which is used.
- (005) availability of trees for harvest=
M3 Currently on each ha of Forest Land
Units: m3
Measure of the total availability of trees for harvest
- (006) BASIC FOREIGN DEMAND FOR LOGS=
1.5e+006
Units: m3/Year
Overall foreign demand for Indonesian logs
- (007) building mills=
max(0,(change in mill capacity needed/TIME NEEDED TO BUILD MILLS) +
SMOOTH(scrapping mills, 1))
Units: m3/Year/Year
Rate at which new capacity is added.
- (008) capacity use=
effect of relative profitability on harvest capacity use(relative profitability of logging)
Units: Dmnl
Fraction of harvesting capacity that is actually used.
- (009) change in mill capacity needed=
desired mill capacity-Wood Processing Capacity
Units: m3/Year
Amount of capacity which needs to be added to create the desired capacity.
- (010) changing demand=
demand difference/TIME NEEDED FOR DEMAND CHANGES TO BE FELT
Units: m3/(Year*Year)

- change in the demand for logs for domestic use by the processing industry
- (011) changing export price=

$$\text{export price difference} / \text{TIME NEEDED FOR PRICE CHANGE TO BE REALIZED}$$
 Units: \$/m3/Year
 changes occurring in the export price
- (012) changing field price=

$$\text{field price difference} / \text{TIME TO CHANGE PURCHASE PRICE}$$
 Units: \$/(m3*Year)
 Changes to domestic purchase price caused by changes in the prices loggers and log sellers would like to have.
- (013) changing foreign demand=

$$\text{foreign demand gap} / \text{TIME NEEDED TO CHANGE FOREIGN DEMAND}$$
 Units: m3/Year/Year
 Changes in the foreign demand for Indonesian logs
- (014) changing price from demand=

$$\text{mill price difference} / \text{PRICE CHANGE DELAY}$$
 Units: \$/(m3*Year)
 Changes to domestic purchase price caused by changes in the prices domestic log buyers would like to have.
- (015) changing price from foreign demand=

$$\text{foreign domestic price difference} / \text{FOREIGN PRICE CHANGE DELAY}$$
 Units: \$/(m3*Year)
 Changes to domestic purchase price caused by changes in the prices exporters would like to have.
- (016) continuous amount cut per ha=

$$\text{amount of timber cut per year} / \text{HA AVAILABLE}$$
 Units: m3/Year
 The per ha cut given the size of the forest available for cutting
- (017) costs of logging etc=

$$\text{EFFECT OF ILLEGAL ARRANGEMENTS ON LOGGING COSTS} * \text{NOMINAL LOGGING COSTS} * \text{effect of availability on logging costs}$$

$$(\text{availability of trees for harvest} / \text{NORMAL AVAILABILITY})$$
 Units: \$/m3
 Given costs of carrying out logging
- (018) Current Domestic Purchase Price= INTEG (

$$\text{changing field price} + \text{changing price from demand} + \text{changing price from foreign demand}, 50)$$
 Units: \$/m3
 Current price paid per cubic meter for logs
- (019) Current Export Price= INTEG (

$$\text{changing export price}, \text{NORMAL EXPORT PRICE})$$
 Units: \$/m3
 The price currently paid for exported logs
- (020) decreasing logging teams=

$$\text{max}(\text{Logging Teams}, \text{Logging Teams} / \text{LOGGING TEAM LIFETIME})$$
 Units: m3/(Year*Year)
 Rate at which timber harvesting capacity decreases.

- (021) demand difference=
adjusted demand-Domestic Demand for Logs
Units: m3/Year
Change needed in demand to match desired demand.
- (022) demand from mills=
Wood Processing Capacity
Units: m3/Year
The demand for logs created by processing mills
- (023) desired mill capacity=
SMOOTH(Wood Processing Capacity*effect of relative product profitability on
desired mill capacity (relative profitability of products), 0.5)
Units: m3/Year
Amount of capacity needed.
- (024) desired mill log price=
Current Domestic Purchase Price*effect of demand on purchase price(relative
demand)
Units: \$/m3
Price the mills expect to pay for logs based on their need to
provide the mills with logs
- (025) Domestic Demand for Logs= INTEG (
changing demand,
demand from mills)
Units: m3/Year
Current demand for logs
- (026) domestic supply=
Supply of Logs-log exports
Units: m3/Year
Supply of logs reaching the domestic market
- (027) effect of availability on logging costs(
[(0,0)-(2,10)],(0.1,8),(0.16,3.54448),(0.244706,2.04982),(0.357647,1.59431
,(0.5,1.2),(0.743529,1.05338),(1,1),(1.25,0.9),(1.5,0.6))
Units: Dmnl
A graphical function describing the relationship between the
timber availability ratio and the effect on logging costs!!!
- (028) effect of demand on purchase price(
[(0,0)-(6,4)],(0,0),(0.2,0.1),(0.508235,0.370107),(0.734118,0.683274),(1,
1),(1.27059,1.28114),(1.72235,1.48043),(2.65412,1.70819),(3.75529,1.90747)
,(5,2))
Units: Dmnl
Graphical relationship of the effect that demand from the mills
has on the price of logs which they buy!!!
- (029) effect of export demand on export price=
effect of export demand on price function(relative export demand)
Units: Dmnl
The effect that the relative demand for exported logs has on the
price of exported logs.
- (030) effect of export demand on price function(
[(0,0)-(6,2)],(0,0),(0.141176,0.149466),(0.5,0.6),(1,1),(1.47,1.3),(2.3,1.45
,(6,1.5))
Units: Dmnl
A graphical function describing the effect that relative demand

will have on the price of exported logs \!relative export demand\!effect on export price Dmnl

- (031) effect of export fraction on foreign price=
1
Units: Dmnl
Function showing the effect the fraction exported has on the effect that export price will have on domestic price. As a starting point this is assumed to be directly proportional to the fraction of logs exported.
- (032) effect of export price on foreign demand=
effect of price on demand function(Current Export Price/
NORMAL EXPORT PRICE)
Units: Dmnl
The effect that the export price has on foreign demand
- (033) EFFECT OF ILLEGAL ARRANGEMENTS ON LOGGING COSTS=
1
Units: Dmnl
Fractional effect of illegal arrangements on logging costs.
Normally illegal arrangements will lower logging costs.
- (034) effect of price on demand function(
[(0,0)-(8,6)],(0,5),(0.150588,3.58719),(0.32,2.60498),(0.508235,1.75089),
(0.724706,1.28114),(1,1),(1.48706,0.854093),(1.99529,0.768683),(3,0.5),(5,
0.1),(6,0))
Units: Dmnl
A graphical function describing the effect that relative export price will have on foreign log demand \!export price/ normal export price\!Effect on Foreign Demand Dmnl
- (035) effect of pricing on amount exported(
[(0,0)-(2,1)],(0,0),(0.272941,0.0213523),(0.5,0.1),(0.564706,0.199288),(0.64,
0.284698),(0.8,0.4),(1,0.5),(1.2,0.6),(1.31765,0.740214),(1.40235,0.846975),
(1.50588,0.925267),(1.75,0.97),(1.99529,0.99))
Units: Dmnl
A graphical function which describes the relationship between export price ratio and the proportion of logs exported \!export price ratio\!proportion of logs exported Dmnl
- (036) effect of product profitability on actual mill use of logs=
effect of relative profitability on mill operations(relative profitability of products)
Units: Dmnl
Effect that profitability of wood product manufacture has on demand for wood at existing mills. If profitability of manufacturing wood products drops then demand will also drop. If profitability increases, then demand will increase, but is limited by the capacity of the mills.
- (037) effect of relative product profitability on desired mill capacity(
[(0,0)-(2,4)],(0,0),(0.09412,0.5125),(0.2447,0.7402),(0.48,0.8541),(0.7435,
0.9253),(1,1),(1.271,1.509),(1.562,2.221),(2,4))
Units: Dmnl
A graphical relationship showing how changes in the profitability of wood products might affect the desire for more capacity.\!\\! Xagressive and holdX
- (038) effect of relative profitability on harvest capacity use(

[(0,0)-(4,2)],(0,0),(0.220183,0.464912),(0.5,0.8),(1,1),(1.5,1.1),
(3,1.1))

Units: Dmnl

Function providing the fraction of harvesting capacity used at each level of profitability.\!relative profitability\!effect on harvest capacity use Dmnl

- (039) effect of relative profitability on logging team increase(
[(0,0)-(6,6)],(0,0),(0.508235,0.597865),(1,1),(1.69412,1.42349),(2.40941,
1.93594),(3.38824,2.90391),(5,5))

Units: Dmnl

Relation showing how profitability of logging causes increases in the number of logging teams needed. \!relative profitability\!effect on capacity increase Dmnl

- (040) effect of relative profitability on mill operations(
[(0,0)-(2,2)],(0,0),(0.235294,0.128114),(0.5,0.42),(0.649412,0.640569),(0.809412,
0.839858),(1,1),(1.19529,1.08185),(1.5,1.1),(2,1.1))

Units: Dmnl

A graphical relationship of the effect of wood product profitability on the use of milling capacity. For example lowered product profitability might lower mill operations and thus lower demand for logs. \!relative profitability\!effect on mill use of logs

- (041) effect of relative supply on price(
[(0,0)-(10,2)],(0,1.1),(0.376471,1.03915),(1,1),(2.63529,0.882562),(4.89412,
0.768683),(7.38824,0.669039),(10,0.6))

Units: Dmnl

effect of the amount of logs available on the price for which they are sold\!relative supply\!effect on log price

- (042) effect of stock ratio on regeneration=
function of effect that stock ratio has on regeneration rate(stock ratio)

Units: Dmnl

As the forest grows the existing forest starts to limit the regeneration rate. This is the output of a graphical function... where the input is the stock ratio.

- (043) effect that export fraction has on the effect of export price=
effect of export fraction on foreign price*fraction of supply exported

Units: Dmnl

The actual amount of foreign exports will have an impact on how important the export price is in determining the domestic log price.

- (044) EXPORT BAN EFFECT=
1+step(-0.99, 15) + step(0.99, 20)

Units: Dmnl

The effect that an export ban will have on exports 0 is fully effective..... 1 is no effect.

- (045) export price difference=
adjusted export price-Current Export Price

Units: \$/m3

The difference between the adjusted export price and the current export price. This difference is gradually absorbed into the current export price.

- (046) export price ratio=

- Current Export Price/Current Domestic Purchase Price
Units: Dmnl
a comparison of the current export price to the current domestic price
- (047) field price difference=
revised purchase price of logs-Current Domestic Purchase Price
Units: \$/m3
difference between the price that suppliers of domestic logs want after accounting for log supply and the current domestic purchase price
- (048) FINAL TIME = 50
Units: Year
The final time for the simulation.
- (049) foreign demand adjusted for price=
BASIC FOREIGN DEMAND FOR LOGS*effect of export price on foreign demand
Units: m3/Year
foreign demand after the effect of price change is taken into account
- (050) Foreign Demand for Indonesian Logs= INTEG (
+changing foreign demand,
BASIC FOREIGN DEMAND FOR LOGS)
Units: m3/Year
- (051) foreign demand gap=
foreign demand adjusted for price-Foreign Demand for Indonesian Logs
Units: m3/Year
Difference between the revised foreign demand and the current foreign demand
- (052) foreign domestic price difference=
(Current Export Price-Current Domestic Purchase Price)*effect that export fraction has on the effect of export price
Units: \$/m3
The difference between current price and export price modified by the fraction of logs exported. For example, if exports are very low then the export price will have little effect.
- (053) FOREIGN PRICE CHANGE DELAY=
0.5
Units: Year
- (054) fraction of supply exported=
log exports/Supply of Logs
Units: Dmnl
Fraction of logs that are actually exported
- (055) function of effect that stock ratio has on regeneration rate(
[(0,0)-(1,1)],(0,1),(0.134557,0.97807),(0.223242,0.95614),(0.327217,0.925439),
(0.431193,0.855263),(0.538226,0.719298),(0.605505,0.52193),(0.669725,0.346491),
(0.779817,0.166667),(0.868502,0.0789474),(1,0),(1.1315,-0.0526316))
Units: Dmnl
\\stock ratio\\effect on regeneration
- (056) HA AVAILABLE=
1e+006
Units: ha

Total hectares of forest land available for harvest

- (057) harvesting=
 $\text{MIN}(\text{M3 Currently on each ha of Forest Land}, \text{continuous amount cut per ha})$
 Units: m3/Year
- (058) increasing logging teams=
 $\text{max}(0, (((\text{Logging Teams Desired} - \text{Logging Teams}) / \text{TIME NEEDED TO INCREASE}) + \text{SMOOTH}(\text{decreasing logging teams}, 1)))$
 Units: m3/Year/Year
 Rate at which logging capacity increases.
- (059) initial stock=
 259
 Units: m3
 The initial standing stock in a forest.
- (060) INITIAL TIME = 0
 Units: Year
 The initial time for the simulation.
- (061) LIFETIME=
 10
 Units: Year
 Average lifetime of capacity.
- (062) log exports=
 $\text{Supply of Logs} * \text{effect of pricing on amount exported}(\text{export price ratio}) * \text{EXPORT BAN EFFECT}$
 Units: m3/Year
- (063) logging employment=
 $\text{amount of timber cut per year} / \text{m3 cut per person per year}$
 Units: people
 numbers of workers needed for log harvest at a given point in time
- (064) LOGGING TEAM LIFETIME=
 0.5
 Units: Year
 Typical lifetime of given units of logging capacity.
- (065) Logging Teams= INTEG (
 $+\text{increasing logging teams} - \text{decreasing logging teams},$
 NORMAL SUPPLY)
 Units: m3/Year
 Current number of logging teams (logging capacity) This includes personnel, chain saws and other equipment.
- (066) Logging Teams Desired=
 $\text{SMOOTH}(\text{Logging Teams} * \text{effect of relative profitability on logging team increase}(\text{relative profitability of logging}), 0.25)$
 Units: m3/Year
 The number of logging teams (capacity) needed, given the current level of profitability.
- (067) M3 Currently on each ha of Forest Land= INTEG (
 $+\text{regeneration} - \text{harvesting},$
 initial stock)
 Units: m3

Amount of harvestable wood currently on the land in question.

- (068) m^3 cut per person per year=
141
Units: m^3 /person/Year
Harvest per person per year. Based on data from Obidzinski
- (069) m^3 processed per person per year=
244
Units: m^3 /person/Year
Amount of wood processed by one mill worker per year
- (070) MARKET PRICE OF WOOD PRODUCTS=
100
Units: \$/ m^3
Current profitability of wood products.
- (071) MAX REGENERATION RATE=
0.05
Units: 1/Year
The fastest fractional rate at which the forest can add useable biomass.
- (072) MAX STANDING STOCK=
350
Units: m^3
Highest standing stock possible
- (073) mill price difference=
(desired mill log price)-Current Domestic Purchase Price
Units: \$/ m^3
Difference between the current price and the desired price that mills want to pay.
- (074) milling employment=
adjusted demand/ m^3 processed per person per year
Units: people
- (075) NOMINAL LOGGING COSTS=
25
Units: \$/ m^3
TYPICAL LOGGING COSTS
- (076) NORMAL AVAILABILITY=
259
Units: m^3
Most wood loggers will encounter on one hectare
- (077) NORMAL EXPORT PRICE=
50
Units: \$/ m^3
- (078) NORMAL PRODUCT PROFIT MARGIN=
50
Units: \$/ m^3
An arbitrary standard for profitability based on m^3 of raw material.
- (079) normal profitability of logging=
25

- Units: \$/m3
Arbitrary base value for profitability of logging
- (080) NORMAL SUPPLY=
3e+006
Units: m3/Year
- (081) potential profit from log harvest=
Current Domestic Purchase Price-costs of logging etc
Units: \$/m3
Calculated potential profit from logging
- (082) PRICE CHANGE DELAY=
0.1
Units: Year
Time needed for prices to reflect actual changes in desired price.
- (083) profit margin due to log price=
MARKET PRICE OF WOOD PRODUCTS-Current Domestic Purchase Price
Units: \$/m3
- (084) regeneration=
M3 Currently on each ha of Forest Land*effect of stock ratio on regeneration
*MAX REGENERATION RATE
Units: m3/Year
Wood being added to trees in a forest.
- (085) relative demand=
(Domestic Demand for Logs)/domestic supply
Units: Dmnl
Comparison of total log demand to current log supply.
- (086) relative export demand=
Foreign Demand for Indonesian Logs/log exports
Units: Dmnl
- (087) relative profitability of logging=
potential profit from log harvest/normal profitability of logging
Units: Dmnl
The profitability of timber harvest compared to normal timber harvest profitability
- (088) relative profitability of products=
profit margin due to log price/NORMAL PRODUCT PROFIT MARGIN
Units: Dmnl
Profitability of wood products compared to an arbitrary standard profitability.
- (089) relative supply=
Supply of Logs/adjusted normal supply
Units: Dmnl
The relative abundance of logs on the market.
- (090) revised purchase price of logs=
Current Domestic Purchase Price*effect of relative supply on price(relative supply)
Units: \$/m3
The price timber suppliers expect for logs after the effect of existing log supply is taken into account.

- (091) SAVEPER =
TIME STEP
Units: Year
The frequency with which output is stored.
- (092) scrapping mills=
Wood Processing Capacity/LIFETIME
Units: m3/(Year*Year)
Rate at which capacity wears out or is retired.
- (093) stock ratio=
M3 Currently on each ha of Forest Land/MAX STANDING STOCK
Units: Dmnl
Ratio of current forest to maximum possible standing stock.
- (094) Supply of Logs=
amount of timber cut per year
Units: m3/Year
Supply of logs coming out of the forest
- (095) TIME NEEDED FOR DEMAND CHANGES TO BE FELT=
0.5
Units: Year
Changes in demand for wood do not have an instant effect on the log market. This is the time it takes for these changes to be absorbed into the system.
- (096) TIME NEEDED FOR PRICE CHANGE TO BE REALIZED=
0.5
Units: Year
time needed for changes in price to be absorbed into the system.
- (097) TIME NEEDED TO BUILD MILLS=
1
Units: Year
Average time needed to install or build capacity
- (098) TIME NEEDED TO CHANGE FOREIGN DEMAND=
0.75
Units: Year
time needed for changes in demand to be realized
- (099) TIME NEEDED TO INCREASE=
0.5
Units: Year
Typical time needed to increase logging capacity
- (100) TIME STEP = 0.0078125
Units: Year
The time step for the simulation.
- (101) TIME TO CHANGE PURCHASE PRICE=
0.5
Units: Year
Average time needed for changes in supply to become apparent...
including transport of logs to the mills.
- (102) Wood Processing Capacity= INTEG (
building mills-scrapping mills,

domestic supply)

Units: m3/Year

Amount of wood processing facilities such as saw mills. It may be necessary to have different models for different aspects of the industry..... saw mills, papermills, plywood mills.