Real Options Valuation of Carbon Sequestration Opportunities in PNW

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Outline

Problem Statement

- **Properties**:
  - `Classical Faustmann Problem:` Choose rotation length to maximize bare land value over multiple harvest cycles subject to silvicultural and economic constraints
  - `Modification:` Introduce risk via stochastic prices of timber and carbon
- **Objectives**:
  - Bare land value with stochastic timber and carbon prices
  - Optimal harvest strategy in stochastic settings
  - Impact of carbon sequestration on optimal harvest age

Stochastic Faustmann Problem as Real Option

`IF` Land ownership is viewed as the right to exchange timber for harvest cost and sell it in the market at prevailing price

`THEN` Valuation of forest land under price risk parallels the valuation of a multi-period American call option

American Call	**Bare Land Value**
Underlying Asset	Timber and Carbon
Contract Length	Planning Horizon
Exercise Time	Harvest Time
Strike Price	Harvest Cost

Solution Algorithm

- Two-part solution:
  - Expected bare land value
  - Optimal harvest policy as function of prices and age
- Many techniques have been developed for valuation of American options
- Monte Carlo algorithm was used for its flexibility
  - Based on method introduced by Ibáñez and Zapatero
  - Extended to calculate value of multiple rotations
  - Modified to solve problems with realistic CO_2 scenarios

Basic Assumptions

- `Bare Land Value:` Calculated in USD per acre
- `Price Models:` Timber and carbon prices assumed to follow a logarithmic mean reverting process
- `Harvest Cost:` Fixed and known at all times
- `Discount Rate:` Fixed and known at all times
- `Silviculture:` Douglas fir regime with planting followed by a regeneration clear cut final harvest
- `Yield Function:` High yield site in Western Washington (No fire, disease or wind risk)

Carbon Treatment

Three basic carbon pools are considered in this study:

- **Forest Pool:** All carbon contained in a standing forest
- **Product Pool:** All carbon contained in harvested wood products
- **Substitution Pool:** All carbon not released into the atmosphere when harvested wood products displace fossil-based alternatives (Avoided emissions)

Cash Flows

- Value at time t:

$$\pi_t = \max\left[CF_C^t + \mathbb{E}[d_t\, \pi_{t+1}^{NH}];\, CF_T^t + \mathbb{E}[d_t\, \pi_{t+1}^{H}]\right] \qquad (1)$$

- Cash flow if harvest does not occur at time t:

$$CF_C^t = \gamma\, \Delta\, Q_t\, P_C^t \qquad (2)$$

- Cash flow if harvest does occur at time t:

$$CF_T^t = Q_t\, (P_T^t - \gamma\, (\alpha_F - \alpha_P - \alpha_S)\, P_C^t - C) \qquad (3)$$

- Where: Q_t = yield; C = harvest cost; α_F, α_P, α_S = fractions of carbon in forest, product and substitution pools; and γ converts carbon in wood to atmospheric CO_2; P_T^t and P_C^t are prices of timber and carbon

Carbon Scenarios

- Scenarios constructed from three sets of values of α_i in equation 3:

$$CF_T^t = Q_t \left(P_T^t - \gamma \left(\alpha_F - \alpha_P - \alpha_S \right) P_C^t - C \right) \qquad (3)$$

Scenario	α_F	α_P	α_S
No. 1	0.80	0.2	0.2
No. 2	0.80	0.25	1.0
No. 3	0.80	0.35	2.0

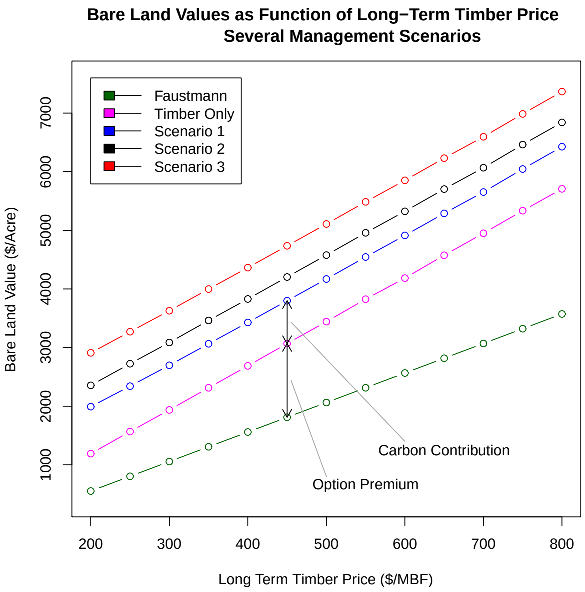
- No. 1: $\alpha_F > \alpha_P + \alpha_S \Rightarrow$ Increased total harvest cost
- No. 2: $\alpha_F < \alpha_P + \alpha_S \Rightarrow$ Increased harvest revenue
- No. 3: $\alpha_F \ll \alpha_P + \alpha_S \Rightarrow$ Increased harvest revenue

Parameter Values

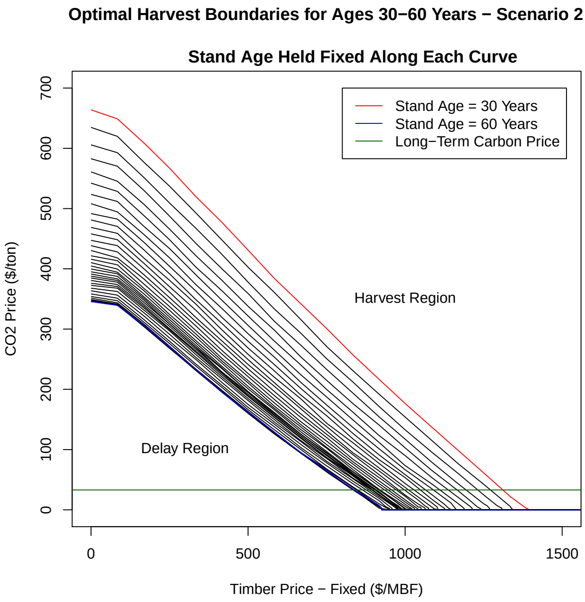
These parameter values were used in all simulations unless stated otherwise

Parameter	Unit	Timber	Carbon
Initial Price P^0		400 ($/MBF)	25 ($/ton)
Long-term Price		665 ($/MBF)	33 ($/ton)
Reversion Rate κ	%/year	0.33	4.0
Volatility σ	%/year	0.25	0.5
Correlation ρ	%	10	
Harvest Cost C	$/MBF	100	
Discount Rate r	%/year	5	
Simulation Horizon T	year	100	
Harvest Time	year	Anytime before T	

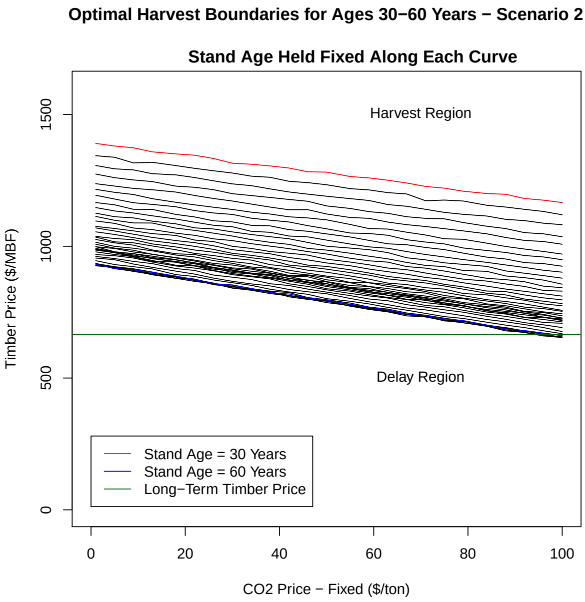
Bare Land Value: Long Term Timber Price



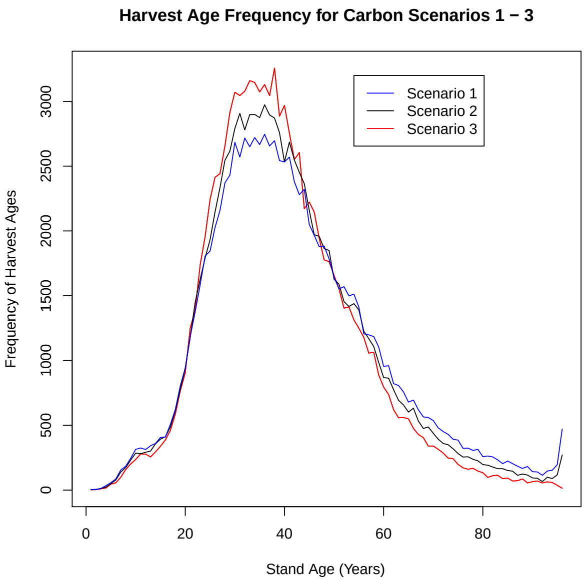
Decision Boundaries - Carbon



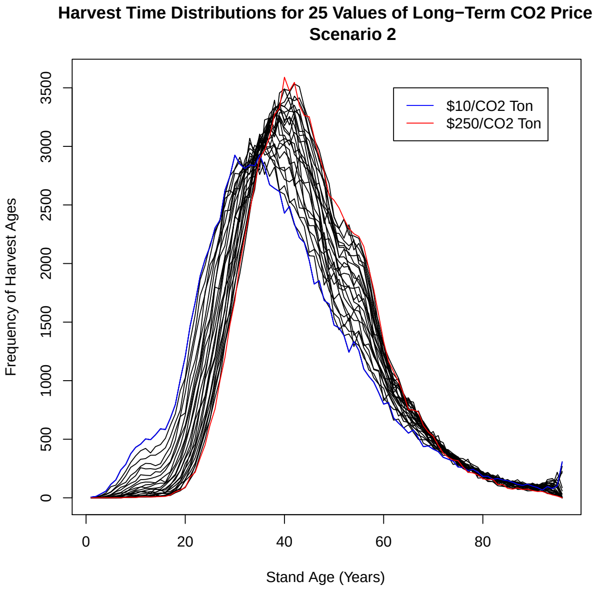
Decision Boundaries - Timber



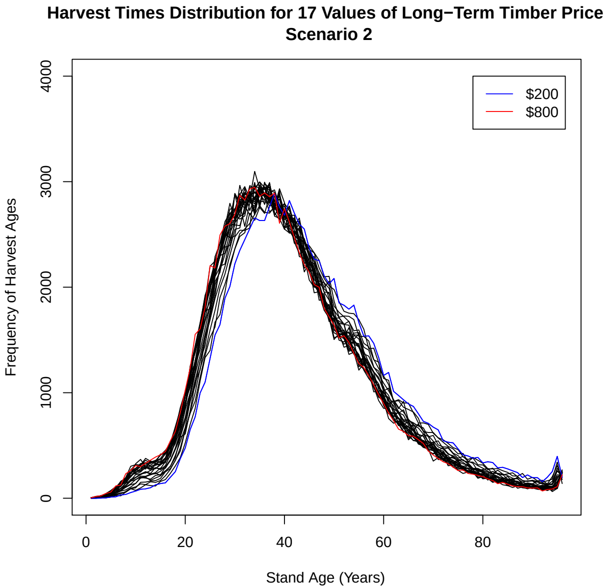
Harvest Age Frequency: Scenarios 1 - 3



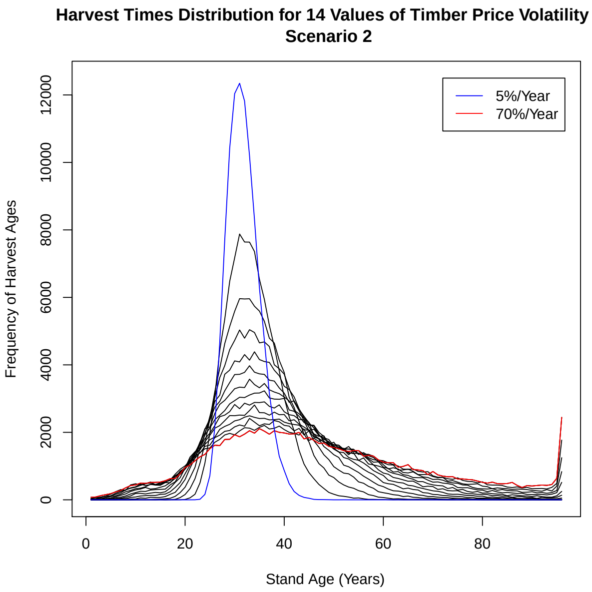
Harvest Time Frequency: CO_2 Price Sensitivity



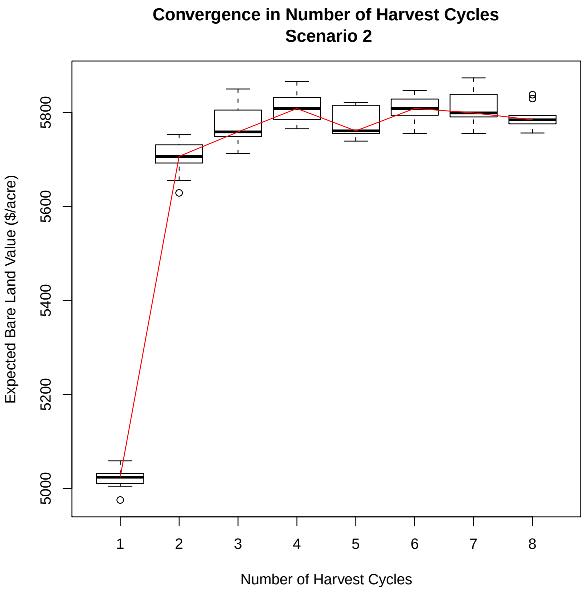
Harvest Time Frequency: Timber Price Sensitivity



Timber Price Volatility Sensitivity



Harvest Cycle Contribution



Summary

- Real options approach provides a practical methodology for determining expected bare land value under stochastic timber and CO_2 prices
- Profitability of carbon sequestration significantly influenced by carbon credit policy
- Future harvest cycles make a significant contribution to expected bare land value under stochastic timber and CO_2 prices

- Outlook
  - More realistic price models
  - Additional sources of risk
  - Faster, more efficient computation

References I

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