

Insurance and forest rotation decisions under storm risk

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Introduction

Forests are often threatened by storms under climate change

- Storms and forests in Europe: **responsible for more than 50% of the European forest damage** over the period 1950-2000.
- Climate change: one of the greatest challenges of our time = **increase of occurrence and intensity of extreme events**
- Various types of **losses both for forest owners and society**: loss of marketability, costs of storage and restoration, losses in other income such as hunting leases or losses of carbon sequestration and amenities.

Risk-hedging strategies

- **Risk-sharing** strategies: **insurance**
- **Risk-reducing** strategies: **reduction of rotation length** in order to diminish both the time of exposure to natural event and the vulnerability of trees due to ageing.

Literature

Review of literature on optimal forest management model

- **Faustmann model** (evaluation of the Land Expectation Value over an infinite sequence of rotation) under risk.
- Main result: **Reduction of optimal rotation under risk.**
- Some **limits**: no risk preferences, no insurance decision.

Review of literature on forest insurance model

- **Static model** of insurance decision and the disincentive role played by **public help** implemented by government after the occurrence of a disaster: Brunette and Couture, 2008; Brunette *et al.*, 2013.
- Determination of the optimal **insurance premium** through an actuarial approach: Brunette *et al.*, 2015.
- Some **limits**: no rotation decision, no dynamic sequential decision problem, no consideration of the insurer's behavior.

Objectives and method

Objectives of the paper

- To **jointly** analyze the forest owner's **insurance decision** and the **rotation age** under storm risk.
- To extend the **Faustmann optimal rotation model under risk**, first, considering the forest owner's **preferences towards risk**, and second, integrating the **decision of insurance**.
- To model the microeconomic **behavior of the insurer** in order to define the components of the insurance contract

Method

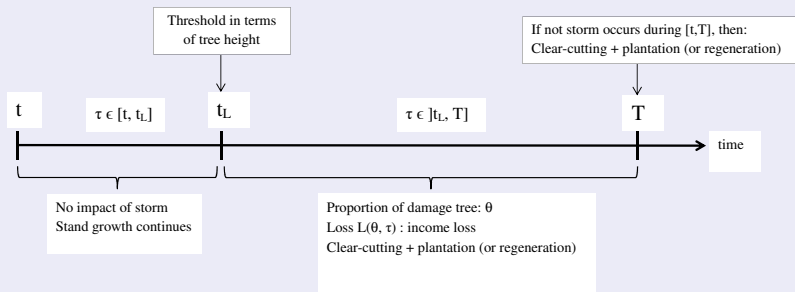
- We adopt an **analytical approach** to model this problem.
- Theoretical model of **expected utility maximization**.

Modeling the risk and the insurance contract

Modeling storm risk

- The occurrence of storm follows a **Poisson process**.
- The distribution of the **times between successive storms** is an exponential with mean $1/\lambda$: $F(x) = 1 - e^{-\lambda x}$ where λ is the expected number of storms per unit of time.
- Let τ be the period of time between the beginning of the stand and, either the storm occurrence or the final harvesting.
- The storm risk is then described by the **couple of random variables** (τ, \mathcal{A}) .
- The **severity of the storm** is given by the random variable \mathcal{A} and is age-dependent by tree-height.

The sequence of events and decisions



Modeling the insurance contract

An insurance contract is defined as a couple: **indemnity, premium**.

- **Indemnity**, $\mathcal{I}(\theta_\tau, \tau)$:

- ▶ If a storm occurs at time τ , the **indemnity** is $\mathcal{I}(\theta_\tau, \tau) = \xi L(\theta_\tau, \tau)$.
- ▶ ξ is the proportion of the loss insured by the forest owner, i.e. the insurance decision.

- **Premium**, \mathcal{P} :

- ▶ The premium is a function of the indemnity, and directly of the loss.
- ▶ $\mathcal{P} = \xi \bar{\mathcal{P}}$ with $\bar{\mathcal{P}}$ the upper premium, per unit of time.
- ▶ $\bar{\mathcal{P}}$ depends on the actualization of future losses for the full coverage of the damage.

The forest owner's program

The forest owner's decision variables

- The forest owner's decision variables are T and ξ .
- Here we determine the forest owner's decision related to the rotation length, assuming a given level of insurance.

The components of the program

- The forest owner is characterized by a vNM **utility function** u with $u'(\cdot) > 0$ and $u''(\cdot) < 0$ to represent risk aversion.
- The forest owner is assumed to **maximize the expected present utility of the net economic return from silvicultural activity**, over an infinite sequence of rotation (the Faustmann value J_F).

The utility for one rotation

- This **utility of the net economic return** \mathcal{Y} , actualized at storm occurrence time τ or logging time T , writes as follows:

$$\mathcal{Y} = \begin{cases} P_0(\underline{t}, \tau) + \mathcal{H}_\delta(\underline{t}, \tau) + u(V_1(\theta_\tau, \tau) + \mathcal{I}(\theta_\tau, \tau) - c_1 - C_n(\theta_\tau, \tau)) & \text{if } t_L < \tau < T \\ P_0(\underline{t}, T) + \mathcal{H}_\delta(\underline{t}, T) + u(V(T) - c_1) & \text{if } \tau = T \end{cases}$$

with:

- $P_0(\underline{t}, t) = \int_0^{\underline{t}} u(-\mathcal{P})e^{\delta(t-s)} ds$, the **insurance premium** paid by the forest owner between the initial time and time \underline{t} , actualized at time t .
- $H_\delta(\underline{t}, t) = \int_{\underline{t}}^t u(h)e^{\delta(t-s)} ds$, the **thinning incomes** between time \underline{t} and time t actualized at time τ .
- $V_1(\theta_\tau, \tau) = (1 - \theta_\tau)V(\tau)$, the **final income** in case of storm occurring at time τ .
- c_1 , the **regeneration (or plantation) cost**.
- $C_n(\theta_\tau, \tau)$ the **clearing costs** for a storm occurring at time τ .

The Faustmann value

- The **Faustmann value** J_F :

$$J_F = \frac{E[e^{-\delta\tau}\mathcal{Y}]}{1 - E[e^{-\delta\tau}]}$$

The program of the forest owner:

The **maximum of the Faustmann value** is obtained by solving:

$$\max_T J_F = \frac{1}{b(T)} \left[\frac{a_0(T)u(-\mathcal{P}) + a_1(T)u(h - \mathcal{P})}{\delta} + W_F(0, T) \right]$$

Proposition 1

Assuming a weak risk averse forest owner for positive income, the optimal cutting age $T_{\mathcal{P}}$ for a given level of insurance, \mathcal{P} , satisfies: $T_{\mathcal{P}} > 0$ and T increases as the degree of insurance coverage ξ increases.

- Cutting age decision and insurance are always used jointly.
- Cutting age decision = risk management tool as self-insurance.
- Cutting age decision and insurance are **substitutes**.

The insurer's program

The components of the insurer's program

- The insurer has to specify the **upper insurance premium** $\bar{\mathcal{P}}$.
- The insurer is assumed to be **risk neutral**.
- The objective of the insurer, J_A , is the difference between the revenue obtained from the insurance premium paid by the forest owner and the expected cost due to the indemnity payment:

$$J_A = \xi \frac{\bar{\mathcal{P}}}{\delta_A} - (1 + l_f) \frac{E[e^{-\delta_A \tau} \mathcal{I}(\theta_\tau, \tau)]}{1 - E[e^{-\delta_A \tau}]}$$

with δ_A , the insurer's discount rate, l_f the classical loading factor.

The choice of the upper premium

- In order to have benefit, the insurer must choose $\bar{\mathcal{P}} > (1 + I_f)\mathcal{P}_0(T)$ where $\mathcal{P}_0(T)$ is the Faustmann value associated to the future losses multiplied by the discount rate δ_A for the cutting age T :

$$\mathcal{P}_0(T) = \delta_A \frac{E[e^{-\delta\tau} L(\theta_\tau, \tau)]}{1 - E[e^{-\delta\tau}]} = \lambda \frac{\delta_A}{b_A(T)} \int_{t_L}^T E[L(\theta_\tau, \tau)] e^{(\lambda + \delta_A)(T - \tau)} d\tau$$

- This condition depends on the cutting age chosen by the forest owner, while in the forest owner's program, the optimal cutting age depends on the upper premium.
- The insurer chooses the upper premium $\bar{\mathcal{P}} = (1 + I_f)(1 + m)\mathcal{P}_0(T)$ (m a security coefficient).

Analysis of the optimal insurance decision

Optimal insurance decision

- Here we determine the **optimal insurance decision considering that the optimal rotation length is given.**
- The program of the forest owner is $\max_{\xi} J_F$.

Proposition 2

Assuming a risk averse forest owner :

- (i) If the discount rates of the forest owner and the insurer are equal ($\delta_A = \delta$) then for cutting age T , the degree of insurance coverage is $\xi = 0$ and the **premium $\mathcal{P}^*(T) = 0$ is optimal.**
- (ii) If the forest owner's discount rate and the insurer's discount rate are sufficiently unequal then for cutting age T , the degree of insurance coverage is $\xi > 0$ and the **premium $\mathcal{P}^*(T) > 0$ is optimal.**

The role of government

“Free public reinsurer”: subsidy for the insurer’s insurance premium

- The government gives a **percentage γ of the indemnity to insurer**: a part γ of the damage is borne by the government while $1 - \gamma$ is borne by the insurer
- The **insurance premium** becomes:

$$\mathcal{P}_0(T) = (1 - \gamma) \frac{\lambda \delta_A}{b_A(T)} \int_{t_L}^T E[L(\theta_\tau, \tau)] e^{(\lambda + \delta_A)(T - \tau)} d\tau$$

Proposition 3

If the discount rates of the forest owner and the insurer are equal ($\delta_A = \delta$), and if the government gives a certain percentage γ of the indemnity to the insurer then an **insurance premium $\mathcal{P}^*(T) > 0$ may be optimal**.

Contributions

- **Extension of the classical Faustmann rotation model** under risk by considering the insurance decision.
- Two supplementary originalities for this paper: to represent the **insurer's behavior** and to consider the **forest owner's preferences towards risk**.

Results

- The forest owner considers that the risk-sharing strategy (insurance) and the risk-reducing one (reduction of the age cutting) are **substitutes**.
- In some cases, it may be optimal for the forest owner to **not adopt insurance**.
- A way to incite forest owners to adopt insurance contract is to consider that the **government subsidizes the insurer**.

Thank you for your attention !