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Harvesting and recovery decisions under uncertainty

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ABSTRACT

A stochastic forest rotation model in the Faustmann tradition is presented and exemplified. The model combines harvesting decisions with the potential to recover or clean up to restore the land after very unfavorable evolutions of the stochastic growth process. Uncertainty is shown to have a generally ambiguous effect on the optimal choice of investment strategy. It is also shown how such models can be related to theory of optimal inventory control.

1. Introduction

Rotation models in Faustmann (1849) tradition address the question of when to cut and re-plant a growing forest on a certain piece of land. Decision problems of this kind have attracted increasing attention in recent years, as evidenced by the quantitative survey in Newman (2002). From a theoretical perspective, this is partly due to the development of real options theory, which has enabled more satisfying specifications of uncertainty than earlier techniques. From an application perspective, it is due to more focus on environmental economics and renewable resources in particular.

Faustmann-inspired models can be described and exemplified in various ways as some kind of harvesting decisions. For simplicity, this paper sticks to the original example with a forest stand that is to be cut and re-planted. The potential income is then a result of physical growth and possible price and quality changes, all characterized by a stochastic process, while costs are fixed. Clarke and Reed (1989) were among the first to assess this stochastic rotation problem in a real options context, but without presenting an explicit solution. Willassen (1998) used impulse control theory when providing an explicit solution under the assumption of a continuous and autonomous Ito forest growth process. Willassen's results were confirmed by Sødal (2002), who used a less sophisticated methodology based on discount factors to derive a simplified closed-form rotation formula. Other recent studies in the field include Chang (2005), who explores the sensitivity of Willassen's Faustmann formula for various parameters in the case with geometric Brownian forest growth, and Alvarez (2004a) and Alvarez and Virtanen (2006), who present conditions under which various stochastic rotation problems are solvable in the linear reward case. The results in Alvarez (2004a) are extended to a general non-linear setting

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in Alvarez (2004b). Alvarez and Koskela (2003) focus on interest rate uncertainty, while Insley and Rollins (2005) develop a two-factor model with linear growth and mean-reverting prices.

The optimal strategy in the standard Faustmann setting consists of cutting the forest stand as soon as a certain net payoff can be obtained. In a deterministic environment, the payoff will be obtained at constant time intervals or rotation periods. In an environment with uncertain growth, the stochastic growth process is usually assumed to be autonomous (independent of calendar time) and still imply cutting and re-planting when a certain payoff can be obtained. However, as conditions can change, some generations of trees grow faster than others so the rotation period will be uncertain.

A decision strategy as outlined above is optimal for many stochastic growth processes but it ignores one option that could be valuable under some assumptions: the option to recover or restore the land in situations when the forest value has declined. Several reasons could explain such a decline, like exceptional weather conditions in certain periods or an unforeseen forest disease. Past bad decisions like a tenure regime that gives inefficient incentives—in which the best trees are harvested and the forest evolves into one with less desirable species—could also increase the risk of decline and a need for a recovery investment of some kind. Under such circumstances there is often strong serial correlation that ought to be reflected, e.g., by switching drift parameters or by letting the growth parameters be influenced by investment.

Regardless of the exact specification, an optimal strategy might exist where forest growth should be restarted (or encouraged in some other way) when things have turned so bad that the likelihood of recovery by nature itself is very low. There will be a net loss in the short run (cashflow deficit) but the investment could still be preferred if it moves the forest out of a miserable state that could otherwise be long-lasting or potentially permanent. Our objective is to describe such options, investigate the circumstances under which they are valuable, and relate the description of the decision problem to previous research.

When discussing this issue, we start out with a model which is close to Saphores (2003) in that it includes the possibility of extinction or terminal decline. However, where he associates extinction with a fixed level of the underlying stochastic variable, we extend to decisions with an endogenous recovery investment based on marginal valuation which need not imply investment at such a fixed level. Recovery after unfavorable growth (i.e., re-planting without reaping a viable harvest) could in principle be a viable option at many stages of a stochastic and unsuccessful growth path, not necessarily at a lower extinction barrier. The characteristics of the problem determine whether it might be better to wait for a natural recovery or to invest to remediate poor growth.

The characteristics of the various models to be discussed, are visualized in Fig. 1. The curved arrows illustrate the uncontrolled motions of value arising from forest growth, while the straight, dashed arrows illustrate the switches controlled by the forest owner. The brackets in the two leftmost charts indicate possible but not required components.

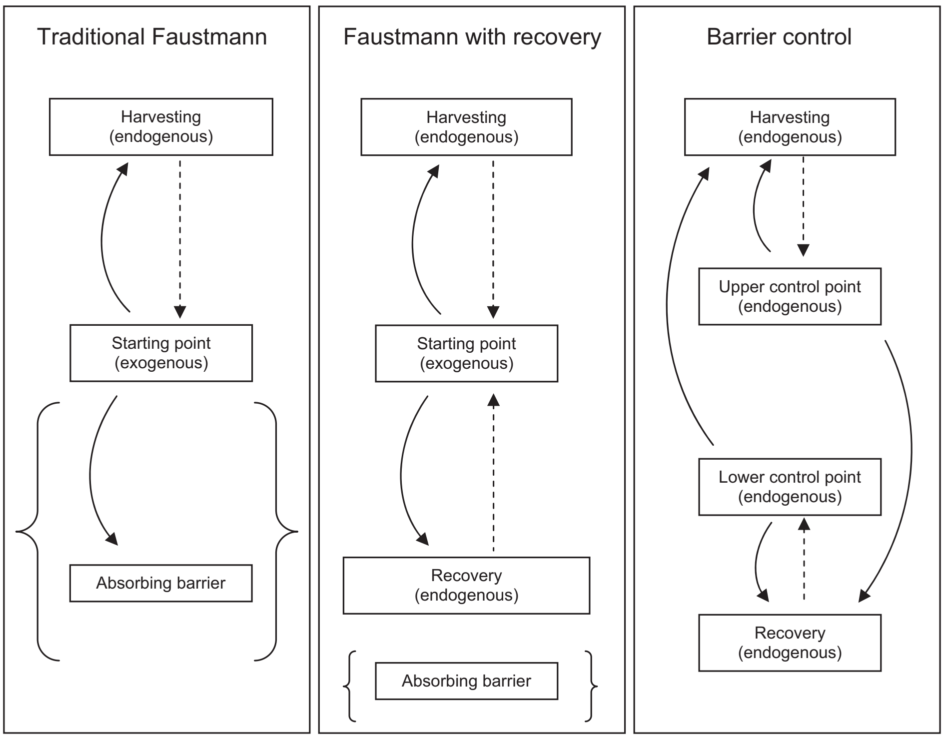

Fig. 1. Rotation models.