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When and to what extent do risk premia work? Cases of threat and optimal rotation

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ABSTRACT

As with financial risk in markets, physical risk (threat or hazard) has sometimes been treated by adding a premium to the discount rate for NPV calculations applied to forestry options. A discount premium reflecting the rate of threat gives the correct rotation for a perpetual succession of crops, and, by simple adjustment, the correct land expectation value, but only if the threat occurs at a constant rate throughout the rotation and if destruction – if it happens at all – is complete. This is true irrespective of the number of intermediate cash flows (e.g. from thinnings). If some value can be salvaged following the destructive event, neither optimal rotation nor NPV is correctly determined by using a threat premium. Partial salvage of value may make the rotation longer or shorter than the threat-free one. A threat-adjusted rate does not give a correct result when threat level changes during the rotation. These findings are illustrated with thinned, wind-susceptible crops in the UK, and crops subject to illicit felling in India.
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Introduction

Within the apparently endless stream of papers on optimal forest rotation, a large and increasing proportion concerns stochasticity, loosely called risk. See Brazee and Newman (1999) for an early review. Among 59 abstracts for a recent Faustmann symposium, 9 were in a dedicated stochastic section, and 12 more referred to stochasticity, risk or uncertainty.

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Deviation from deterministic time sequences comes from many sources: climatic events and variation, biological invasions and infections, human transgressions, market variations, political changes. Within financial markets, risk, narrowly defined, is regarded as variability of production and prices, and hence of profit outcomes. The capital asset pricing model (Sharpe, 1964), treats risk by (upward) adjustment of the discount rate, unless the variation is uncorrelated or negatively correlated with that of investments generally. Thus financial investments with variable outcome are considered less attractive and less likely to be adopted.

For real investments, appropriate treatment of variability is less clear. For example, when variability of yield or crop price impinges on human survival, loss of mean expected utility through time may be more extreme than is modelled by a negative exponential process. In a risky world, the utility of increasing investment in a risky portfolio may *grow* through time; and, though the utility of increasing a riskless investment may grow even more, the relationship of those changed utilities, again, is not a negative exponential (Price, 1993, chapter 11).

For investments, such as forestry, maturing only after a long period, the usual single-valued upward adjustment of discount rate for risk is even less appropriate (Klemperer et al., 1994). It has been demonstrated (Lohmander, 1987; Yin and Newman, 1995) that both net present value (NPV) and optimal rotation length are increased by price fluctuation. These results, arising from greater possibilities of adaptive response with longer rotation, conflict with the effects of discount rate premium. They have been reproduced for different models: for example, log-normal diffusion, random-walk (Brownian motion), geometrical Brownian motion, and mean-reverting prices (for discussions, see Thomson (1992), Penttinen (2006), Gong and Löfgren (2009)); and for fluctuations in interest rate (Alvarez and Koskela, 2006).

Also frequently treated under the heading of risk are unpredictable events that threaten physical survival of forest crops: fire, storm, mammal or insect attack, or depredations by human agents. These, unlike narrowly defined risk, monotonically reduce expected value in relation to risk-free value as time elapses. To clarify the distinction from simple variability – which does not affect mean expected outcome – these factors will be referred to as *threat*. They constitute the focus of what follows.

Many papers have treated the climatic, biological, anthropogenic and political factors which may suddenly reduce or eliminate a forest crop's value. Some have assumed that the threat would destroy all value, as by catastrophic fire (Routledge, 1980; Martell, 1980; Reed, 1984; Caulfield, 1988) or by major human transgression (Price and Trivedi, 1994). These and others have relaxed assumptions about total value loss under threat (e.g. Goodnow et al., 2008), and about constant rate of threat through the crop rotation (e.g. González et al., 2005). Spatial interaction between stands has also been explored (Lohmander and Helles, 1987; Meilby et al., 2001), as have management interventions which may mitigate threat (Thorsen and Helles, 1998), and the implications of threat for non-market values (Englin et al., 2000).

This paper does not add to this body of often sophisticated modelling work. Instead it returns to an earlier era, when it was proposed that the rate of physical threat, added to the discount rate, gave a threat-adjusted discount rate for NPV calculations: again, particularly in optimal rotation determination (Reed, 1984; Clark, 1990). In what circumstances is this adjustment appropriate, where is it *not* appropriate, and what then are the direction and magnitude of error resulting from the adjustment? In particular, how are optimal rotation and the land expectation value (LEV) derived therefrom affected?

The approach

Where threat to the crop exists, the marginal condition for an optimal rotation without intermediate cash flows is:

$$V'(t) = \frac{(\lambda + \rho)(V(t) - C)}{1 - e^{-(\lambda+\rho)t}} \tag{1}$$

where $V(t)$ is crop value at age t, λ is the continuous annual rate of threat, ρ is the continuous rate of discount and C is the regeneration cost.

When $V(t)$ is a simple function, the condition might be solved algebraically. When the function is complex, solution may require iteration. When no algebraic function is defined, but only a numerical

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