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Hans Fredrik Hoen (eds.)

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Optimal Rotation under Continually – or Continuously – Declining Discount Rate

Colin Price
School of the Environment and Natural Resources
Bangor University
Gwynedd LL57 2UW, UK

Abstract

It has been argued from a number of perspectives that the discount rate might decline with increasing period of discounting. With a stepped profile of decline, financially optimal rotations are quite likely to occur at a few discrete ages. For any form of declining discount rate, successor rotations will lengthen, and this will affect the optimal length of earlier rotations. But if rotation length is reassessed periodically, successor rotations will be adjusted downwards from those deemed optimal by a prior generation – a standard problem of dynamic inconsistency. This adjusted sequence of rotations will be deemed by the original decision makers to be less valuable than a sequence of lengthening rotations, and this may affect their own choice of optimal rotation. Whether, and how much, adjustment is appropriate, depends on the reasons underlying the decline of discount rates.

Key words: declining discount rate, optimal rotation, dynamic inconsistency

Introduction

So much has been written about the optimal forest rotation, that it seems implausible for there to be any further aspect of the topic to explore. Yet recent interest in a schedule of declining discount rates has reopened the topic.

The effect of high discount rates on long forest rotations is particularly severe, such that investing in products like veneer oak could hardly be justified under any conventional investment appraisal. Instead, fallacious arguments have been raised which seek to link the costs of investment with revenues derived from the previous rotation (Garfitt, 1986).

An alternative avenue has been to question the whole ethical basis of discounting, particularly the discounting of *utility* or of *totalities*, as opposed to discounting of marginal consumption in a context of growing total consumption. The ethical case against discounting is especially plausible in a context of sustainable development: discounting seems the ideal means of "compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

More recently, it has been argued from a number of perspectives that the discount rate might decline with increasing period of discounting, so that long forest investments are given advantage over other investments. Such a decline in discount rate reflects human psychological propensities (Strotz, 1956; Ainslie, 1991; Loewenstein, 1993), which may or may not be irrational. Otherwise, in general a reduced discount for longer periods can be derived by combining two or more different individual discounting profiles or protocols:

- different generations (Kula, 1981; Bellinger, 1991; Bayer, 2003; Sumaila and Walters, 2005);
- groups experiencing different income growth rates (Price and Nair, 1985);
- different goods (Price, 1993);
- different scenarios of future scarcity (Price, 1997; Gollier, 2002);
- different development paths for interest rates (Newell and Pizer, 2001);
- different perspectives on the future (Li and Löfgren, 2000).

For the purposes of this paper it does not matter much what the source of the discount profile is. Details of the process, and arguments against using the general approach, are outlined in Price (2004, 2005).

Apart from persistent instances of Kula's rather idiosyncratic modified discounting (Kula, 1986), applications in forestry have so far been rather sparse. Hepburn and Koundouri, 2007) apply six different discounting protocols, including four with declining rates, to three representative forest investments with different rotations. From this they draw the expected conclusion: that long-term forestry investments (oak in Scotland) are more affected by declining discount protocols than are short-term ones (pine in Uganda). The urge among mainstream economists to reinvent the known results of forest economics has persisted since the times of Samuelson (1976), and still seems to be active.

While over the years much effort has been devoted to evaluating the effect of *different* discount rates on rotation, the effect of *varying* the discount rate as rotations unfold, seems to have been little examined. This paper looks at the results of applying discount rates that step downwards from time to time (continual decline), and ones that move relentlessly downwards (continuous decline). It identifies some procedural problems in calculating optimal rotations, and some problems of consistency in attempting to apply rotations calculated on such a basis.

Stepped and fitted profiles: continual and continuous decline

Several possible profiles of discount factors with declining discount rate are shown in figure 1. The UK Treasury (undated), following guidance from OXERA (2002), which in turn was based on Newell and Pizer (2001), has advocated a schedule of discount rates "stepped" downwards periodically, as displayed in table 1.

Table 1: continually declining discount rate

Period (years)	Discount rate
0–30	3.5%
30-75	3%
75-125	2.5%
125-200	2%
200-300	1.5%
>300	1%

The "fitted" protocol of discount rates shown below is based on regression of logarithm of discount rate on time, from this stepped sequence. The "cumulative" protocol builds up a discount factor year by year, using the discount rate scheduled for that year. Thus for, say 80 years, the discount factor would be

$$\frac{1}{1.035^{30}} \times \frac{1}{1.03^{45}} \times \frac{1}{1.025^{5}}$$

This procedure avoids the *discontinuities* in the profile displayed by the "stepped" function, although there are still *kinks* in the curve. The "conventional" protocol uses the fixed 3.5% rate with which the Treasury schedule of rates starts.

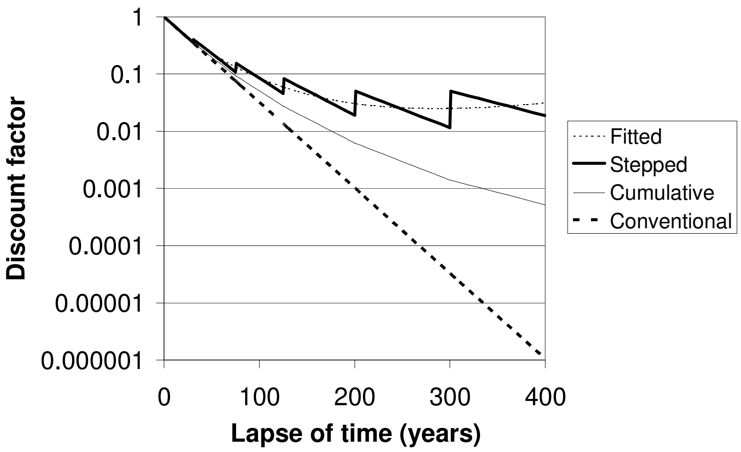

Figure 1: Four profiles of discount factors

Many other profiles might be derived from different sources (see Price, 2004 for examples). But the ones displayed suffice for demonstrating effects on forest rotations.

An hypothetical revenue function reflecting both volume growth and price–size relationship is represented in figure 2. To simplify calculations and clarify results, a no-thinning regime is adopted. Management costs are considered invariant to rotation length. This function was used, with some modification of parameters, in all subsequent modelling.

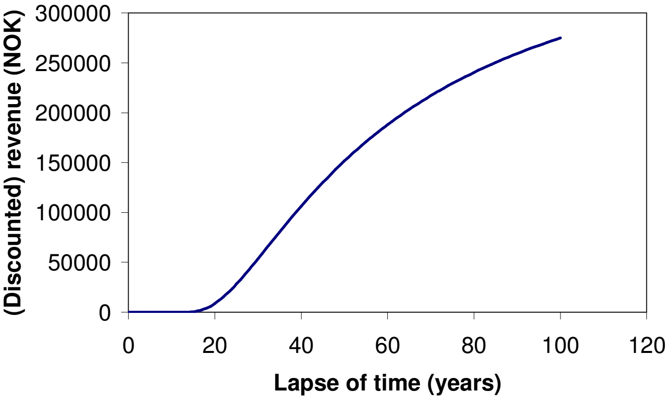

Figure 2: The basic revenue function

An optimal single financial rotation is the one maximising discounted revenue. With a stepped profile of decline, optimal single rotations generally occur at a few discrete ages. Figure 3 gives one example, typical of many. There is a local optimum at around 50 years, but maximum discounted revenue is achieved at 76 years, immediately after the discount rate steps down to 2.5%. Data labels show the optimum according to the fitted discount function, with a maximum discounted revenue of NOK 24,722 whereas according to this function the discounted revenue at 76 years is NOK 22,897. This is almost 10% lower, purely as a result of using the stepped function.

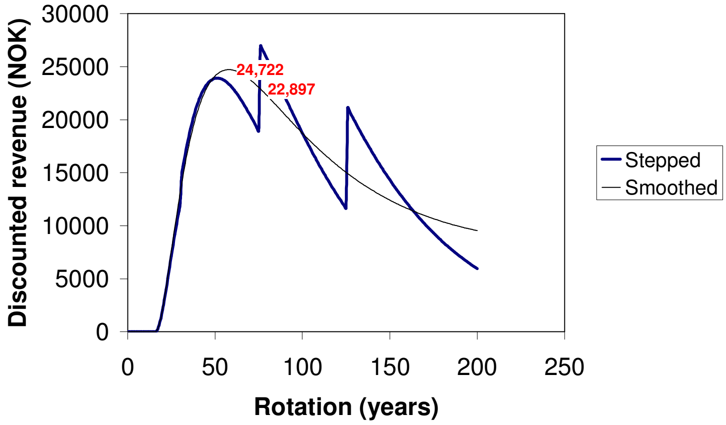

Figure 3: Stepped discounting and discrete rotation length

But the fitted function itself has problems: the discount factor *increases* beyond about 300 years. Thus it might appear desirable to extend a rotation, even if a 300-year-old crop was no longer growing. For subsequent cases, the more tractable and reasonable cumulative function is used.

Land expectation value

Once successor rotations are included in a land expectation value (LEV), three problems arise from the lower rates that apply to later periods.

- Successive rotations become progressively longer.
- Rotations *of the same length* would have *different value*, even when discounted to their start time.
- These factors affect the future opportunity cost of land, and so influence the length of earlier rotations.

Therefore, no simple formulation for land expectation value can be constructed, by applying the usual multiplier to the NPV of a single rotation.

Instead, an incremental and numerical approach is adopted. The optimal single rotation is successively shortened, until the reduction in NPV of the present rotation is just balanced by the gain from bringing forward the NPVs of successor rotations (which represents the opportunity cost of land for a year). Note that, as rotations get shorter, subsequent rotations may move into different “discount zones”, and so have to be *recalculated*, not just *brought nearer*. For example, revenues might now be discounted at a higher rate with a shortening of the successor rotation, but costs discounted at the same rate.

With the cumulative discount function, the discount rate stabilises at 301 years, and this is reflected in constant single rotations commencing thereafter, as shown in figure 4. The same would be expected for series of rotations. In fact, however, in the present calculations only ten rotations are considered. Thus, as successive rotations are initiated, there are fewer future rotations to include, so the opportunity cost of land for subsequent rotations is reduced (and reduced significantly, given the 1% discount rate in force by then). Thus for the last rotation the optimal length of a series of rotations (a series of one) is the same as for a single rotation, although the two are calculated by different processes.

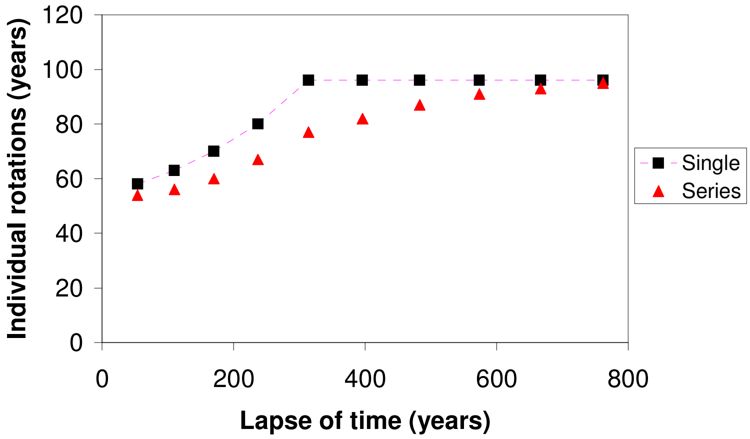

Figure 4: Optimal rotations with declining discount rate

Because the system is optimised by an iterative process in which adjacent rotations are modified in small steps, and because the discount rate changes sharply at kinks in the discount function, the search for an optimal sequence of rotations may be affected by instability. Chaotic behaviour during optimisation arises particularly with the stepped function. Optimal rotation occurs when rate of change of NPV with rotation length changes sign, and this happens several times, once at each of the steps in the discount function. A new search protocol is being developed to circumvent this problem.

Fundamentally, however, the model seems to be reliable: it generates the expected constant rotation length when a constant 3% discount rate is used.

Dynamic inconsistency

As long as declining discount rates have been discussed, it has been observed that they will lead to "dynamic inconsistency" (Strotz, 1956). That is, a decision which appears optimal at one point in time will no longer seem so from a later point. This has led to proposals that decisions made from the present perspective should be made binding, if it is possible (Elster, 1984).

In fact, restrictive covenants or legislation have been used to lock in rotations, e.g. in Sweden and Lithuania. However, it seems unlikely that an attempt to lock in a sequence of lengthening rotations could be feasible, even for existing forests, let alone for ones yet to be planted. A particular bizarre case may be quoted from Price (2004), illustrated in table 2.

Table 2: Options for Scots pine (*Pinus sylvestris*) rotation

Event	Cash flow per hectare	Discounted value seen from time AD 2004	Discounted value seen from time AD 2084
Establish	–£2000	–£2000	
Fell at age 80	£6000	£6000 × 0.26513 = £1591	£6000
Fell at age 120	£12000	£12 000 × 0.25215 = £3026	£12 000 × 0.35653 = £4278

> Suppose Scots pine (*Pinus sylvestris*) is established on a low productivity site, with cash flows per hectare as shown in [table 2]. Discount factors for 40, 80 and 120 years are 0.35653, 0.26513 and 0.25215, derived by summing utilitarian and conservationist factors …. From the perspective of AD 2004, a rotation of 120 years appears profitable. However, in AD 2084 the revenue from immediate felling exceeds the discounted revenue from delaying until AD 2124. The crop is felled at age 80 years. Yet, had that felling age been anticipated at the time of establishment, the crop would not have been deemed worth planting.

Here, it would be “correct” in the perspective of the present generation to enforce a 120-year rotation. But, if the present generation claims the right of making its own decisions, why should not any future generation also claim that right? Rather than making naïve decisions based on its own preferences, the present generation should make a sophisticated decision, based on its understanding of future generations’ likely preferences. It should not plant.

A further unsettling example is provided by a case modified from that shown in figure 4, with establishment cost increased to NOK 15,000. Now, as figure 5 shows, the first rotation is unprofitable, because of relatively heavy discounting between now and 58 years (≥3%) The next rotation, however, falls in a period when the discount rate changes from 3% to 2.5%, and this is sufficient to bring the second rotation into profit. Subsequent rotations, while also profitable, are sufficiently distant that their contribution to LEV declines, even though the discount rate continues to fall. Overall, LEV is positive.

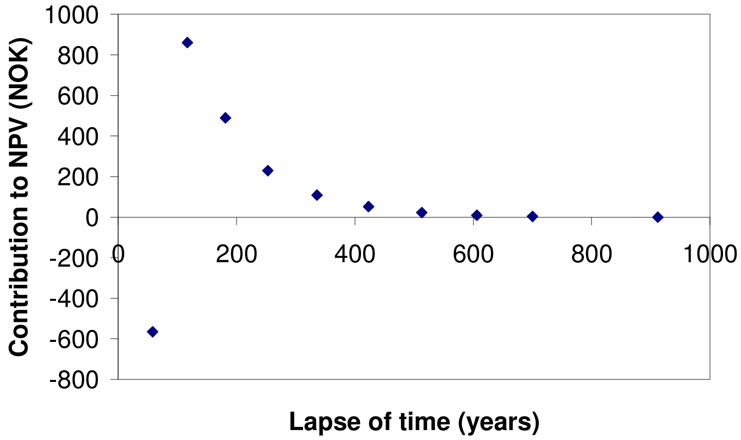

Figure 5: Change in perceived profitability between rotations

The first, naïve, instinct of the present generation might be to establish the forest, because of the positive LEV. The second instinct might be not to establish it, but to provide for its being established in 58 years' time. The third might be to predict that the second rotation will not be planted, on the same grounds as used for not planting the first. Thus every generation accepts that forestry should be the long-term use of the land, and every generation leaves it to the next to start the process.

The final instinct might be to adopt a flexible, state-dependent approach, which predicts the probability that circumstances (e.g. the track of interest rates) will change in each of a number of ways. But this is appropriate only if the change in discount rate arises from real change in circumstances, rather than from shifting time perspective. If the latter, it can confidently be predicted that future generations will make decisions in a similar self-interested and short-sighted way to the present one.

There is a problem even if the first rotation is profitable. The *most profitable* sequence of rotations, seen from the present perspective, will be adjusted to a sequence which the present generation deems *less profitable*, with the consequence that future opportunity cost is less, and its own preferred first rotation length should be longer.

Conclusion

As was said at the outset, declining discount rates arise from combinations of two or more different discount functions. The proper way to deal with these circumstances is to incorporate these functions explicitly. For example landscape values might be discounted at a low rate on grounds advocated in Price (1973) or Fisher and Krutilla (1975). They will become progressively more important in relation to timber values, and the effect will be a successive prolongation of rotations (Calish et al., 1978), perhaps eventually reaching a stage where timber is no longer cut, or is cut in a manner that leaves forest cover intact. Yet such a protocol is based on the specifics of this particular case and its combination of products. To apply to it a set of third-hand discount rates, wheelbarrowed in from some central government office, is to misunderstand the nature of the case for giving the future greater consideration than conventional discounting would do.

When the shift in discount rate is due, not to changes attached to position in Earth history, but rather to a shifting time perspective, discounting is revealed as simply an assertion of the primacy of the present generation over all others. Although this reflects how humans think and act, it is no longer a politically fashionable position. It never *was* ethically defensible.

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