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Discounting Environmental Effects in Project Appraisal

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Summary

The aim of this paper is to present an alternative methodology for discounting far distant future externalities generated by an investment project; time-declining discount rates. First I present the experimental evidence on individuals'time-inconsistency. Second I consider the theoretical justification for using hyperbolic discounting in a simple uncertainty framework where marginal social utility is discounted hyperbolically if the investing Government believes that social wealth might increase or decrease over future period with a small probability that wealth will deteriorate below its current level.

Keywords: Environmental effects, project appraisal, social discounting

JEL: Q01, D61, H5

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1 Introduction

All projects create some demand on natural resources since they have either positive or negative environmental effects. For this reason, recent policy debate has stressed the importance of considering the sustainability in the investment analysis process.

In particular, if environmental effects can be quantified, they must be valued and also discounted in the same way as other costs and benefits. However the use of ordinary discount rates remains controversial. The transfer of the concept of discounting, used typically for relative short-term productive sector projects with tangible marketed outputs, to the appraisal of often long-term and normally high uncertain environmental effects has caused considerable discussion among economists. The "ecological solution" is one of using a very low or zero discount rate applied only to environmental effects in order to account for future generation.

The present article aims to provide some support to the idea that exponential discounting for project costs and benefits do not take into account some recent acquisitions of psychology and economics. In fact, there is quite strong empirical evidence that people discount the future hyperbolically with larger annual discount rates to near-term that to returns in the distant future.

In this note I ask: *Can we use hyperbolic discount function rather than exponential one for public project appraisal?* My answer is that we might use it for distant environmental effects and if Government believes that social welfare might increase in future with a relatively small probability that it will decrease..

The paper is organized as follow: in section 2 and 3 I present a review of experimental evidence and theoretical literature, section 4 contains some notes on the use of hyperbolic discounting in a project appraisal framework and 5 contains the conclusion.

2 Environment in economic project analysis

In economic theory concerning optimal allocation over time of natural resources, a representative single agent is assumed. The total consumption at time t is C_t and the utility function is $U(C_t)$. The optimal path $\{C^*\}$ maximizes the social welfare function $W(\cdot)$.

Let us assume that people make decision on the basis of Present Value (PV), defined as:

$$PV = \sum_{t=0}^{\infty} U(C_t) F(\tau) \tag{1}$$

In this model, people confront a wide range of critical choices that involve trade-offs between current and future rewards concerning environmental effects. As stated in the Introduction, to evaluate such trade-offs, decision makers compare costs and benefits of activities that occur at different date in time. In (1), consumer discounts utility with a discount function $F(\tau)$, where τ is the delay between the current period and the future consumption and it is assumed to be decreasing in τ with $F(\tau) \geq 0 \ \forall \tau$. Since the model is normalized, in what follows we consider:

$$1 = F(0) \geq F(\tau) \geq F(\tau') \geq 0$$

for $0 < \tau < \tau'$. If $\tau \in \{0, \Delta, 2\Delta, 3\Delta, ...\}$, then we can write the welfare of the consumer at time t as:

$$PV = \sum_{t=0}^{\infty} U(C_{t+\tau\Delta}) F(\tau\Delta) \tag{2}$$

At horizon τ, the discount rate is:

$$r_t = -\frac{\frac{F(t)-F(t-\Delta)}{\Delta}}{F(t)}$$

and the discount factor is:

$$f(\tau) = \left(\frac{1}{1+r(\tau)\Delta}\right)^{\frac{1}{\Delta}} = \left(\frac{F(t)}{F(t-\Delta)}\right)^{\frac{1}{\Delta}}$$

Almost all discounting applications use the exponential discount factor: $F(\tau) = e^{-\delta t}$ and consider the discount rate and the discount factor as constants and do not depend on the horizon:

$$\begin{aligned} r_\tau &= -\frac{F'(\tau)}{F(\tau)} = \delta \\ f(\tau) &= e^{-r(\tau)} = e^{-\delta} \end{aligned}$$

As a growing body of experimental evidence shows that people time preference structure is inconsistent with the constant discount rate of exponential discounting, in next sections we consider the case of time inconsistency as a valuable alternative in decision making, especially in economic appraisal of environmental effects.

3 Experimental evidence on time inconsistency

Recent experimental evidence on individuals' behavior suggests that people have a taste for instantaneous gratification, so that discount functions are hyperbolic.

An example taken form Kocherlakota (2001) could better explain basic concepts:

> "*Jan is about to go out to her neighborhood bar. Before drinking anything there, Jan would like to sign a legally binding contract stating that she is allowed to drink only four beers that night. Why does she want to sign such a contract? She knows that after having four beers, she will want to have a fifth, and she wants to prevent her self from doing so*"
>
> [Kocherlakota (2001), p. 13]

Jan is exhibiting time-inconsistent preferences: her preferences for beer, at a given date and state, change over time without the arrival of new information.

Several models of time-varying discount rate have been developed by economists. Robert Strotz (1956) was the first one who studied time-inconsistency in a dynamic framework:

> "*Special attention should be given, I feel, to a discount function...which differs from a logarithmically linear one in that it "over values" the more proximate satisfaction relative to the more distant ones...My own supposition is that most of us are "born" with [such] discount functions...*"
>
> [Strotz (1956), p. 177 quoted in Thaler (1981), p. 201-202]

Phelps and Pollak (1968) introduced hyperbolic discount functions in an intergenerational context on consumption and saving. They capture taste for immediate gratification with a simple two-parameter model that modifies exponential discounting. Let u_t be the instantaneous utility of a person in period t. Then her intertemporal preferences at time t, U^t, can be represented by the following utility function, where both β and δ lie between 0 and 1:

$$U^t(u_t) = \delta^t u_t + \beta \sum_\tau \delta^t u_t$$

The parameter δ determines how "time-consistently" patient a person is. If $\beta = 1$, then these preferences imply exponential discounting. But for $\beta < 1$, these preferences are time-inconsistent.

Decrease in timing aversion has been observed in experimental studies concerning: people choosing between non-monetary alternatives [see Solnick et alii (1980); Christensen and Szlanski (1984), Millar and Navarick (1984) and Cropper et al. (1992)]; people choosing between monetary alternatives [Thaler (1980); Ainslie and Haendel (1983), Horowitz (1988) and Benzion et al. (1989)]; animals choosing between types of food or between other alternatives [Raichlin and Green (1972); Ainslie (1975); Ainslie and Herrnstein (1981)]. As Harvey (1994) argues, many of these studies do not examine the decrease in people's discount rate as it becomes large but rather the increase in their discount rate as time becomes small. Loewenstein and Prelec (1992) compare violations of constant discounting to the much more studied violations of expected utility as they observe that:

> "*unlike [expected utility] violations, which in many cases can only be demonstrated with a clever arrangement of multiple choice problem (e.g. Allais paradox), the counter-examples to DU [constant discounting] are simple, robust and bear directly on central aspects of economic behavior*"
>
> [Loewenstein and Prelec (1992)]

As noted above, the main justification for the adoption of the hyperbolic discounting utility function is empirical evidence in the cognitive psychology literature which contradicts the predictions of utility functions with stationary fixed discount rates. Harvey (1994) considers two types of experiments in the literature on the test of hyperbolic discounting hypothesis.

The first type is discussed first by Thaler (1981). Some people prefer "one apple today" to "two apple tomorrow" to "one apple in one year". Ainslie and Haslam (1992) reports that

> "*a majoirty of subjects say they would prefer to have a prize of $100 certified check available immediately over $200 certified check that could not be cashed before 2 years; the same people do not prefer a $100 certified check that could be cashed in 6 years to a $200 certified check that could be cashed in 8 years*"
> [Ainslie and Haslam (1992)]

Experiments of this type have been replicated with choices involving a wide range of goods and a wide range of subject populations.

The second class of experiments is discussed in Thaler (1981) and Benzion et al. (1989). Subjects were asked to imagine that they had won a sum of money in a lottery and that they could either take the money now or wait for an increased amount later. They were presented with several variations of the amount $\$x$ at time t and $\$y$ immediately, then we say that the subject's choice is consistent with the discount rate $\delta(x,t)$ defined by the equation

$$y \equiv \delta(x,t)^t x$$

The results show that the average discount rate is decreasing in t. However, it was also found that $\delta(x,t)$ is not constant but it is an increasing function of x. The larger the sum of money at stakes, the higher (closer to 1) the discount factor.

Rubinstein (2000), on the contrary, using experimental results, argues that the same sort of evidence which rejects the standard constant discount utility functions can reject hyperbolic discounting as well. Furthermore, a decision making procedure based on similarity relations better explains the observations and is more intuitive.

4 Some few notes on theoretical literature

An increasing number of theoretical papers has been published in recent years.

Laibson (1994 and 1997) studies a one-person intertemporal decision problem of consumption and saving. His main findings are that we can distinguish an hyperbolic economy from an exponential one in two ways:

1. hyperbolic discounting implies that the elasticity of intertemporal substitution is less than the inverse of the coefficient of relative risk aversion;

2. hyperbolic discounting explains many features of the policy debate about undersaving.

Laibson's model suggests that financial innovation may have caused ongoing decline in U.S. savings rate, since financial innovation increases liquidity, eliminating commitment opportunities.

Barro (1999) modified the neoclassical growth model to allow for a non-constant rate of time preference. He finds that if the household cannot commit future choices of consumption and if utility is logarithmic, then the equilibrium resembles the standard results.

Krusell and Smith (2000) try to answer the question: *How do individuals with time-inconsistent preferences make consumption-savings decisions?* They consider a simple form of consumption-saving problem, assuming people discounting in a quasi-geometric way. They find that when time horizon is infinite, the dynamic game played between a price-taking consumer's successive selves is characterized by several equilibria. This multiplicity takes two forms:

- there is a continuum of stationary points for the consumer's asset holdings;

- for each stationary point there is a continuum of paths leading into this stationary point.

Krusell, Kuruscu and Smith (2000) consider a representative-agent equilibrium model where the consumer, as usual, has quasi-geometric time preference and cannot commit future actions. The planner is a consumer representative who, without commitment but in a time-consistent way, maximizes his present value utility. The competitive equilibrium results in strictly higher welfare than does the planning problem whenever the discounting is not geometric.

5 Hyperbolic discounting and project appraisal

In this section I present some reflection and a simple theoretical rationale concerning the use of hyperbolic discounting in a project appraisal framework.

The neoclassical theory of project evaluation (Arrow and Kurz, 1970) is based on models in which agents discount the future at a constant exponential rate: the choice between two payoffs depends only on the absolute time interval separating them.

On the contrary, there are at least three reasons to consider using a time-declining discount rate:

1. there is strong empirical evidence that individuals use lower discount rates for events that occur farther into the future;

2. a large enough positive discount rate gives negligible weight to costs and benefits that occur far into the future, using a time-declining rate avoids having to choose between ignoring very long-term environmental consequences (with a time-invariant, nonzero rate) and not discounting at all (Weitzman, 1999);

3. current market rates of interest or marginal rates of time preference reflect the preferences of individuals currently alive, not those not yet born. In other words, future impacts should have exactly the same weight as current impacts.

By using Nir (2000) approach, let us consider a simple world with three periods: 0 for the present, 1 for the near future and 2 for the far distant future. Let us also assume that negative environmental effects from a public investment are positively correlated with purely economic benefits. In period 0 social welfare is W and for each monetary unit of benefit society gains, the marginal welfare diminishes by 1 because of environment deterioration. Government perceives future welfare fluctuating between periods after the investment, but not falling below current wealth.

In the first period, society might gain a benefit unit with probability p_1. If it does not gain in period 1, it might obtain an economic benefit in period 2 with the same probability. However, if society gains in the first period, in the next period it might have an additional unit with probability p_2^w, lose with probability p_2^l, and neither gain or have a welfare deterioration with probability p_2^n, where $p_2^w + p_2^l + p_2^n = 1$. Table 1 summarizes the expected social welfare functions from an additional benefit unit unit.

Insert table 1 about here

Since

$$W > W - p_1 > W + (p_1)^2 - (W+1)p_1 + p_1 \left[p_2^w (W-2) + p_2^l (W-1) + p_2^n W \right]$$

expected additional welfare declines over time.

Proposition 1 *The expected marginal social welfare from economic benefits is hyperbolic when* $p_2^w < p_1 + p_2^n < 1 + p_2^w$.

Proof. *Note that the marginal social welfare is discounted in an hyperbolic way when there is a perception that future marginal wealth effects are decreasing at a decreasing rate as a function of time. The difference between expected marginal social welfare in period i-1 and in period i is defined as* Δ_i*, thus*

$$\Delta_i \equiv E\left[W_{i-1}\right] - E\left[W_i\right]$$

In order to show that the discounting is hyperbolic, the following relation must be held:

$$\Delta_1 - \Delta_2 > 0$$

Substituting probabilities from Table 1 we get:

$$\Delta_1 = p_1$$

$$\Delta_2 = p_1\left(1 + p_2^w - p_1 - p_2^n\right)$$

The marginal welfare is hyperbolic when $\Delta_1 - \Delta_2$ *and* $\Delta 1$ *are positive and* Δ_2 *is not negative.* Δ_1 *is always positive by definition.* Δ_2 *is negative when* $p_1 + p_2^n < 1 + p_2^w$*, while* $\Delta_1 - \Delta_2$ *is positive when* $p_2^w < p_1 + p_2^n$*.* ■

The intuition of Proposition 1 is that p_1 must be large enough so that expected welfare function will not decrease in the second period, but small enough so that welfare will not decrease much, causing the decrease in social wealth between periods 1 and 2 to be smaller than between periods 0 and 1.

In order to demonstrate a rationale for the use of time-inconsistent preferences in project analysis, we need to show that small earlier net social value will be preferred in the near future and the larger later one in far distant future. To this point Table 2 shows the social welfare from an additional little more than economic benefit (i.e. 1+0.1) under the same conditions in Table 1. The only difference between the tables is that in Table 2 I increased welfare by 0.5 for each possible level of wealth.

Insert Table 2 about here

Proposition 2 *The Government should allow for inconsistent preferences in investment appraisal when the probability of winning the first unit of economic benefit is large enough, $p_1 > 0,5$, and the probability to have a wealth deterioration is large enough $p_2^n > p_1 + 0,5 - \sqrt{2}$.*

Proof. *It is necessary to show that:*

$$E_0 [W(1)] > E_1 [W(1.1)]$$

and

$$E_2 [W(1.1)] > E_1 [W(1)]$$

Substituting expected welfare function from Tables 1 and 2, the first condition holds when $p_1 > 0,5$, and the second one when $p_2^n > p_1 + 0,5 - \sqrt{2}$.
■

The intuition of Proposition 2 is that the probability of obtaining benefits in the first period must be large enough to diminish the expected welfare for the larger later net social value (LLV) in period 1. In that case, smaller earlier one (SEV) will be preferred in period 0 to the LLV in period 1, which is the near-future trade-off. The probability of deteriorating the wealth in the second period must be large enough so that the expected additional welfare in the second period will not be too small. Thus in the second period LLV will be preferred to the SEV in the first period, which is the distant future trade-off.

Previous propositions suggest that it may be essential to incorporate declining discount rates into any cost-benefit analysis for evaluating long term environmental effects generated by projects.

Thus, in the world described by such theorems, the question is: *When is the far-distant future?*

Newell and Pizer (2001) find that costs and benefits in the distant future such as those associated with global warming, long-lived infrastructure, hazardous and radioactive waste, and biodiversity often have little value today when measured with conventional discount rates. They demonstrate that when the future path of this conventional rate is uncertain and persistent (i.e., highly correlated over time), the distant future should be discounted at lower rates than suggested by the current rate. They then use two centuries of data on U.S. interest rates to quantify this effect. Using both random walk and mean-reverting models, they compute the certainty-equivalent rate that is, the single discount rate that summarizes the effect of uncertainty and measures the appropriate forward rate of discount in the future. They estimate discount factors over the next 400 years based on a 4% rate of return in 2000. Discount factors are expressed in terms of the value today of $ 100 provided at various points in the future, that is, the discount factors multiplied by 100. After only 80 years, conventional discounting at a constant 4% undervalues the future by a factor of 2, based on the random walk model. Going further into the future, conventional discounting is off by a factor of over 40.000 after 400 years. The mean-reverting model produces less huge yet still significant results, raising the discount factor by a multiple of about 130 after 400 years. Newell and Pizer find also that the difference between valuations using different initial rates is smaller when uncertainty about future rates is incorporated.

6 Conclusion

The presence of uncertainty about future discount rates provides a rationale for using hyperbolic discount function in long term effects appraisal.

From a positive point of view, Weitzman (1999) defines two implications:

1. the declines in discount rates could be a significant phenomenon such that one might use hyperbolic discounting for any cost-benefit analysis of the effects in far-distant future;

2. it would be better to consider, for social choices the low-interest-rate situation because, *ceteris paribus*, that situation will carry relatively more weight in determining the expected difference between present discounted benefits and costs.

Besides, theoretical literature should make an effort to provide a methodology to smooth estimated environmental externalities over the future. It should also be noted that if we define the long term period as *after 100 years*, it is too difficult to allow for future effects generated i.e. by an infrastructure because the relatively small dimension of the investment project if compared to climate change mitigation program or biodiversity preservation policy.

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Table 1

Additional Welfare from a benfit unit	Period 0	Period 1	Period 2
W	1	$1-p_1$	$(1-p_1)^2+p_1p_2^n$
$W-1$	0	p_1	$(1-p_1)\,p_1+p_1p_2^l$
$W-2$	0	0	$p_1p_2^w$
Expected Additional welfare	$W+1$	$W+1-p_1$	$W+1+(p_1)^2-(W+1)p_1$ $+p_1[p_2^w\,(W-2)+$ $+p_2^l\,(W-1)+p_2^nW]$

Table 2

Additional Welfare from a benefit of 1,1	Period 0	Period 1	Period 2
$W+0,5$	1	$1-p_1$	$(1-p_1)^2+p_1p_2^n$
$W-0,5$	0	p_1	$(1-p_1)\,p_1+p_1p_2^l$
$W-1,5$	0	0	$p_1p_2^w$
Expected Additional welfare	$W+0,5$	$W+0,5-p_1$	$W+0,5+(p_1)^2-(W+1)p_1$ $+p_1\,[p_2^w\,(W-1,5)]$ $+p_1[p_2^l\,(W-0,5)+$ $+p_2^n\,(W+0,5)]$

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