The Economics of time discounting

Andreas Markoulakis

Warwick Summer School

An outline of the lectures

- Lecture 1: An introduction to economic risky decision making. Expected Value and Expected Utility.
- Lecture 2: Beyond Expected Utility: Prospect theory, non-linear probability weighting, loss aversion, WTA/WTP gap.
- Lecture 3: The economics of time discounting. A brief history of time preferences and the models used to describe time preferences.
- Lecture 4: Applications of time discounting in fields of economics, with a particular focus on environmental economics.

In today's lecture

- In the lecture today we will talk about intertemporal choice and time discounting.
- The concept of discount factor and discount rate will be introduced in the context of different modelling approaches and how discount rates can be affected.
- We will examine applications on under-savings for retirement, appraisal for long term projects with particular reference to climate change, capital investment decisions and health state valuations.

Intertemporal choice

- Apart from risk, there is another important factor that could well affect attitudes: the time dimension, that is, what happens when investment decisions have to be taken at different points in time.

- What happens when one has to consider such future choices? How one can model such economic situations? Let's see a couple of examples.

What would you choose:
One apple today
Two apples tomorrow

Consider another problem.
One apple in 100 days
Two apples in 100 days plus one day

What would you choose:
- £500 now or £540 in 3 months from now?

- The question that emerges is how much does a future monetary outcome worth right now (at the present)?

- You should consider a trade-off between an outcome (not necessarily a monetary reward) available now and something else available in the future (temporally distant).

- This consideration is the notion of the intertemporal choice.

A brief history

- John Rae (1834) was probably the first who studied intertemporal choice by referring to the “desire for accumulation” as a major reason to explain the wealth of nations.
- He made particular references about the uncertainty of human life and the desire for immediate consumption over deferring it to the future.
- Eugen von Boehm-Bawerk also studied intertemporal choices and in particular he modelled such choices as allocation of consumption across different time periods (trade-offs).
- Later, Irving Fisher modelled the insight of Boehm-Bawerk in an indifference curve map (current vs future consumption).
- Then, in 1937 Paul Samuelson introduced the exponential discounting model.

What is discounting?

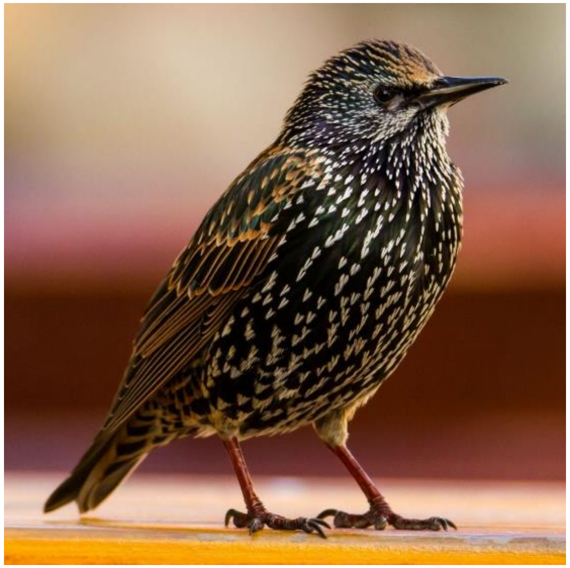
- A discounting process refers to the devaluation (i.e. reduction in value) of a quantity, say Y, to a lower value y.

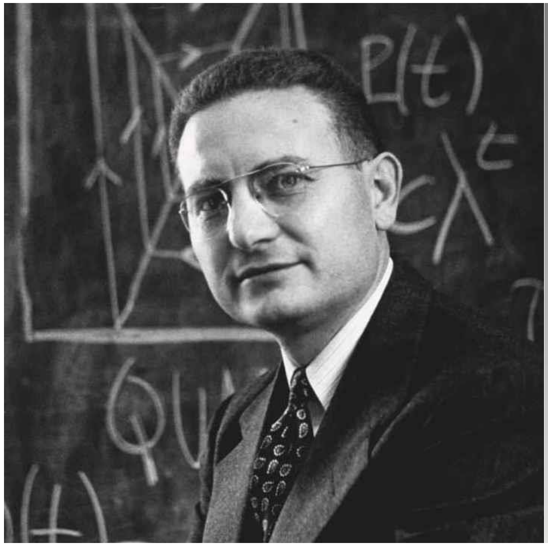
- Mathematically, it is described by the simple formula $y = T(t) * Y$ where $T(t)$ is the discounting factor. Note that the discount factor is a function of time.

- It is not necessary the quantity to be only money; it could be energy variables, food/water etc.

Not just for human beings

- Examples of intertemporal choice are not confined to human beings only.
- In fact, the literature on hyperbolic discounting started with experiments on birds (pigeons, starlings) and then expanded to human beings.
- George Ainslie, a psychiatrist was one of the pioneers in examining intertemporal choice in animals. Howard Rachlin was also a pioneer in the field of behavioural psychology.





Paul Samuelson (1915-2009) (Nobel laureate, 1970) introduced the exponential discounting model in 1937.

George Ainslie (1944-)

Howard Rachlin, (1935-2021)

Three pioneers in the study of intertemporal choice

A simple example-How it works in practice

Assume you have £100, and you invest them in a scheme that has an annual interest (discount) rate of $r\%$.

Then the (present) value of your money after 1 year would be

$$PV = \frac{100}{1+r}$$

After n years the present value would be: $PV = \frac{100}{(1+r)^n}$

The term $\frac{1}{1+r}$ is the discount factor.

A similar example can be considered when there is a stream of flows to be estimated, like purchasing a bond.

For a bond that makes payments £100 per year, the present value is

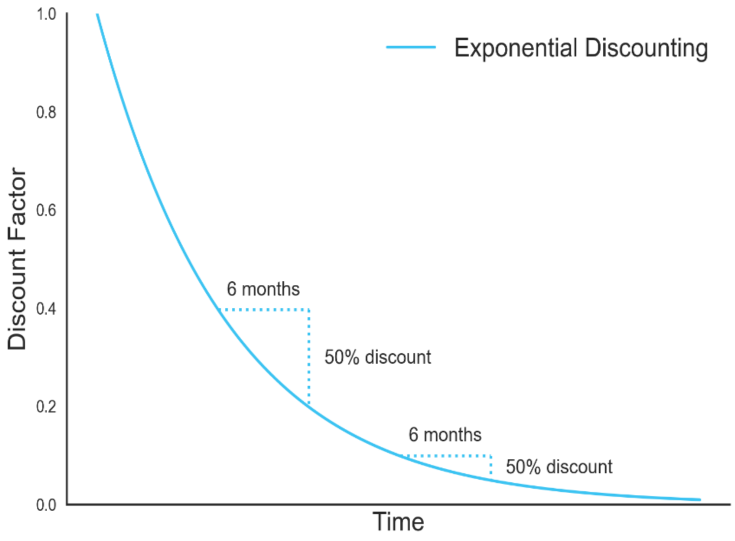
$$PV = 100 + \frac{100}{(1+r)} + \frac{100}{(1+r)^2} + \cdots + \frac{100}{(1+r)^n}$$

The upshot: future payments have to be discounted i.e., how much £100 in 5 years worth right now?

To give concrete answers one needs a functional form for the discount factor.

Exponential discounting-The norm in economics

- Exponential discounting is the most popular approach in modelling the time dimension.
- The crucial implication of this model is that the discount rate (how fast discount factor changes) is constant.
- This implies that consumption amendment at two different dates only depends on the time difference between these dates (if this is violated, a common difference effect arises). This is called dynamic consistency.



Exponential discounting

- How to model exponential discounting? It was Samuelson in 1937 who introduced this model in economics.

- The formula for the exponential discounted utility model is

$$Y = \frac{1}{(1+r)^t} * y$$

and for a flow of utilities across time is

$$U(c) = \sum_{t=0}^{T} \frac{1}{(1+r)^t} u(c_t)$$

- A continuous time analogue formula is $T(t) = e^{-rt}$. So, intertemporal utility can be written as

$$U(c) = \int_{t=0}^{T} e^{-rt} \, u(c_t)$$

Exponential discounting

- From the continuous case, one can show that the discount rate is constant (and equal to r) and is defined as below:

$$r(t) = -\frac{(e^{-rt})'}{e^{-rt}} = -\frac{-re^{-rt}}{e^{-rt}} = r$$

Of course the above holds only for differentiable discount functions.

- Note that Samuelson (1937) had reservations about the validity of this modelling approach and he concludes:

"In conclusion, any connection between utility as discussed here and any welfare concept is disavowed. The idea that the results of such a statistical investigation could have any influence upon ethical judgments of policy is one which deserves the impatience of modern economists."

Psychological components of time preferences

- Briefly I will refer to the "dimensions" of time preferences. In mainstream economic papers, these concepts are being "masked" by a general discussion about time discounting and elicitation of time preferences.
- Frederick et al. (2002) refers to three such concepts: impulsivity, compulsivity and inhibition.
- The most relevant for economist is impulsivity, the extent to which people act in a spontaneous way. This behaviour tends to reveal a high discount rate.

- We will see this concept in the example about drug addicts. Economists occasionally refer to impulsivity when they examine time preferences.

Psychological components of time preferences

- Compulsivity refers to the tendency of people to make plans and stick to them, that is, doing something regularly, a repetitive behaviour. This implies low discount rates.

- Inhibition refers to the inhibition of impulsive behaviour, containing behaviour instincts e.g. resisting to junk food. This could imply low discount rates.

- The above two concepts are not commonly discussed in economic applications.

An example

- Let's assume a utility stream i.e., a sequence of utilities.
- Consider the notation that t=0 corresponds to the present. Then, t=1 is for the next (first period), t=2 for the period after (second period) and so on and so forth.

- The corresponding utilities are:

$$u_0, \text{ for } t = 0$$

$$u_1, \text{ for } t = 1$$

$$u_2, \text{ for } t = 2$$

$$u_3, \text{ for } t = 3$$

An example

	$t = 0$	$t = 1$	$t = 2$
A	1	0	0
B	0	3	0
C	0	0	2
D	1	2	3

Let's try to estimate now the utility for each of the four choice patterns. The formula that will be used is:

$$U(c) = u_0 + \delta u_1 + \delta^2 u_2 + \delta^3 u_3 + \cdots = \sum_{t=0}^{T} \delta^t u(c_t)$$

An example

- In the previous representation, δ is nothing more than the discount factor we discussed earlier. This is how we devalue the future.
- It is $0 \leq \delta \leq 1$.
- What δ indicates for time preferences?
- The closer the discount factor is to 1, then the agent exhibits patience while if δ is closer to 0, then the agent exhibits impatience.

An example

- What are the utilities for each choice pattern? Consider that $\delta = 0.9$.

$$U(A) = u_0 = 1$$
$$U(B) = \delta u_1 = 0.9 * 3 = 2.7$$
$$U(C) = \delta^2 u_2 = 0.9^2 * 2 = 1.62$$
$$U(D) = u_0 + \delta u_1 + \delta^2 u_2 = 1 + 2.7 + 1.62 = 5.32$$

Between A,B,C what is your choice?

You would choose B

Between A,B,C,D, what is your choice?

You would choose D

An example

- You could try to see what happens with a different discount factor, say $\delta = 0.7$.
- What does change? If anything?

Generally, the lower the discount factor one has, the more impulsive that person is and could lead even to damaging behaviour.

The higher the discount factor, the less impulsive a person would be. This could have an impact on his/her behaviour.

Hyperbolic discounting

- Despite the simplicity of the exponential discounting model, a large body of research has shown that this modelling approach is not confirmed.

- In particular, it has been shown that time discounting is not always a steady process as exponential discounting implies and that discount rate can change across time.

- Another feature reported is that discounting occurs at a higher rate in the short run than in the long run (so, discount rate declines across time). This means that people are more impatient when they have to make some short-run choices than when they face long-run choices.

- A formula that describes hyperbolic discounting is

$$T(t) = \frac{1}{1+kt}$$

then, the discount rate depends on time

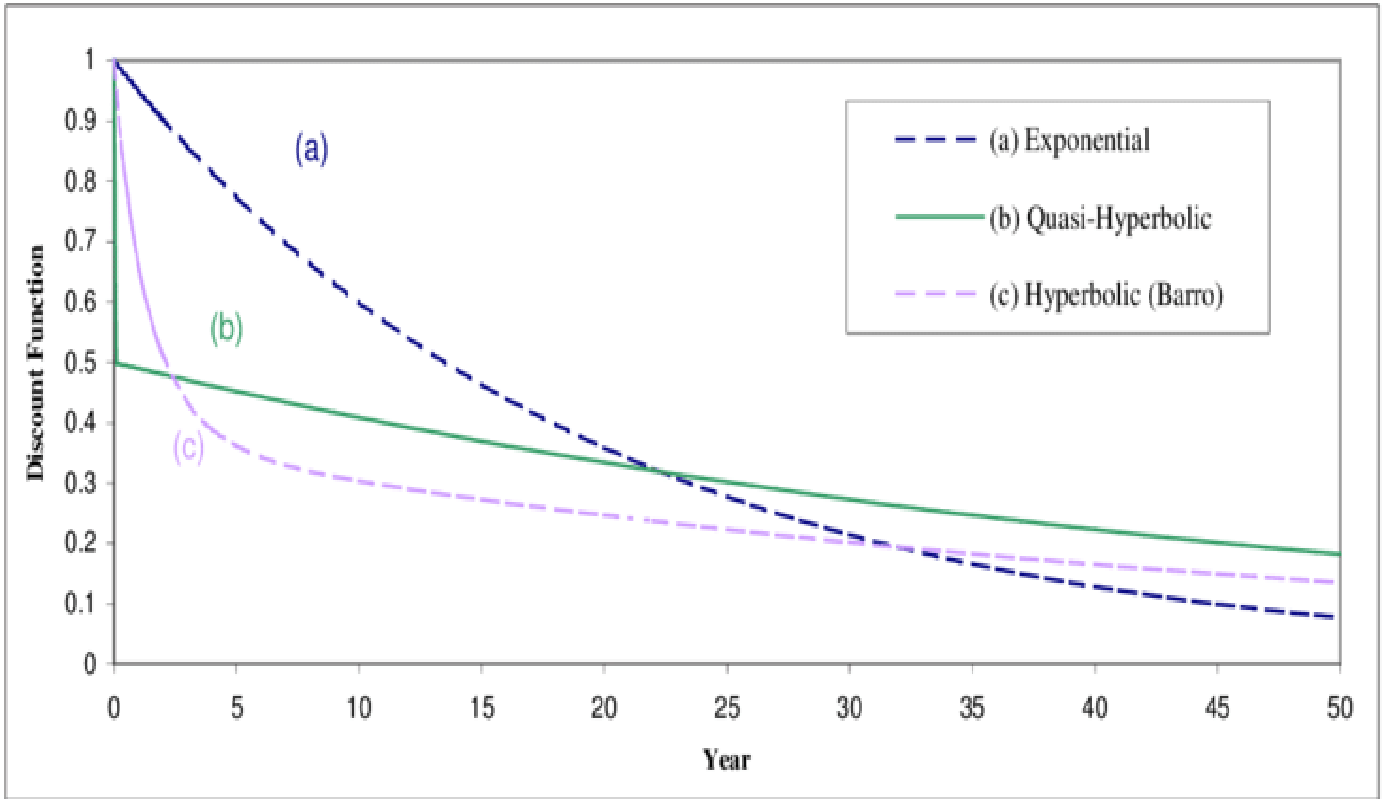
$$-\frac{T'(t)}{T(t)} = \frac{k}{1+kt}$$

- Then, intertemporal utility is written as

$$U(c) = \sum_{0}^{t} \frac{1}{1+kt} u(c_t)$$

- The discount factor is inversely related to time (as time passes discounting continues). The larger the k, the steeper the discounting.

In general, hyperbolic discounting will discount future rewards more than exponential discounting in the short run but this will reverse in the long run (for lengthy delays). It can be seen in the following graph.



Generalized hyperbolic discounting

There is not a single formula to describe hyperbolic discounting. The following formulas have also been proposed

$$T(t) = \frac{1}{t}$$

$$T(t) = \frac{1}{(1 + \alpha t)^{\frac{\beta}{\alpha}}}, \alpha > 0, \beta > 0$$

The latter formula represents the “generalized hyperbolic discounting” approach.

If $\alpha = \beta$, then it collapses to the previous hyperbolic discounting formula.

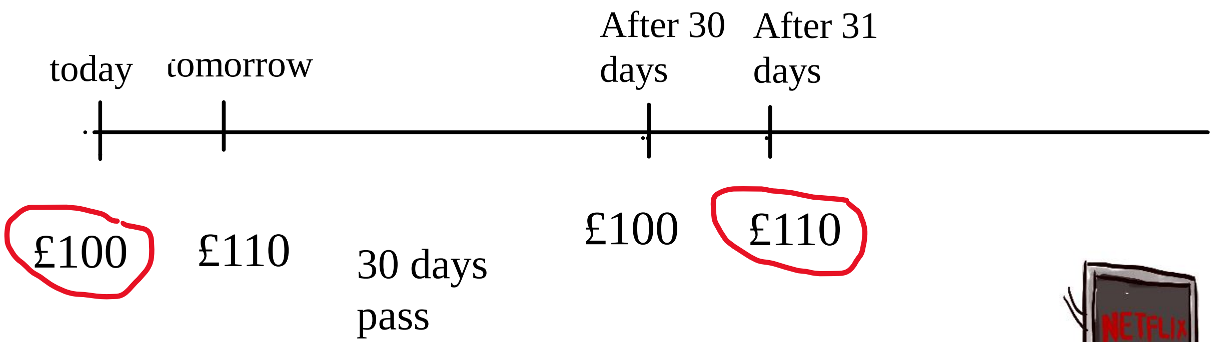
Ramifications- Dynamic inconsistency

An important ramification of hyperbolic discounting is that discount rate declines as time passes. In economics, it was Richard Thaler who was one of the first who indicated this back in 1981.

Another implication is the dynamic inconsistency issue that arises: one might choose one apple today to two apples tomorrow but the same person when the choice is reconsidered after 100 days could well choose two apples (in 101 days) to one apple (in 100 days). This is called preference reversals (dynamic inconsistency) (Thaler, 1981).

The concept of comparing a smaller sooner (SS) reward to a larger later (LL) reward is common in intertemporal choice.

Richard Thaler
Nobel Laureate, 2017



If we attempt to visualize choices across time it would something like above: a smaller sooner reward (£100) vs a larger later reward (£110) with the only difference that the question is repeated after a particular time period (here 30 days).

People might initially prefer £100 but after 30 days they might prefer £110.

- This implies present bias i.e., subjects put more weight on the value of a present than a future reward.

- From another perspective: (see the graph in the next page) at sufficient delays for both rewards, an individual might prefer the LL reward.

- However, as both rewards approach in time, the individual’s preference might reverse (at point A) so that the individual to choose the SS reward.
- You might call the interval during which the SS reward is preferred the “window of vulnerability” during which when choosing the SS reward results in an impulsive behaviour.

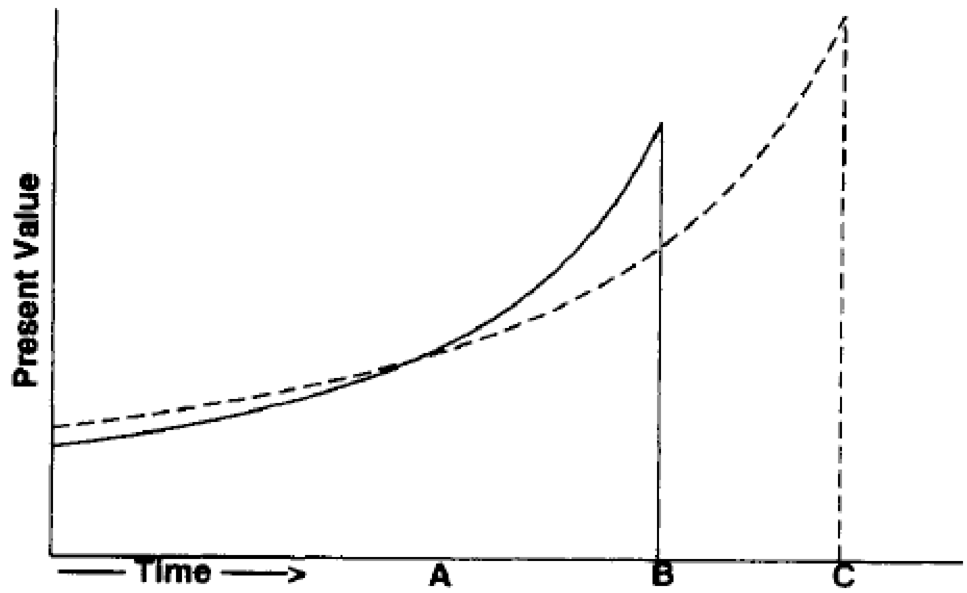


Figure 1. Present, discounted values of two delayed rewards as a function of delay. *B* indicates the point of receipt of a smaller, sooner reward, and *C* indicates the point of receipt of a larger, later reward. With the passage of time, preference reverses from the larger to the smaller reward at point *A*.

Source: Kirby et al.(1999).

Dynamic inconsistency in real life

- Dynamic inconsistency could lead to a number of problems in real life. For example, one might want to go to bed early and enjoy his/her sleep but on the other hand you discover there is a movie you like which is available in your local theatre and you stay up late in the night to watch it.

- Generally, this means that people cannot stick to their plans and this can have important side-effects e.g., not saving enough money for the future (we will see this example).

- Of course, there is always the question of whether sticking to a plan or choice beforehand is the correct decision.

Quasi-hyperbolic discounting

- In economics, a popular discounting approach is the quasi-hyperbolic discounting approach popularized by (Laibson, 1996):

$$T(t) = \begin{cases} 1, & t = 0 \\ \beta\delta^t, & t = 1,2,3,\ldots \end{cases}$$

where parameter β ($\beta < 1$) describes present bias – then as time passes, payoffs additionally discounted by δ.

This is in essence a hybrid model which captures the impulsivity in the short term (present bias). When $0 < \beta, \delta < 1$, the model has a high discount rate in the short run and a lower discount rate in the long run.

If $\beta = 1$, the model collapses to exponential discounting approach.

Quasi-hyperbolic discounting

- Quasi-hyperbolic discounting has become popular in the last decades in economics.

- An important reason for this is the analytical tractability of the model given its close association with the exponential discounting model.
- Also, the fact that it can explain time inconsistent behaviour and emphasize the emphasis many people put in the present (present bias) makes it a useful model for economists.

- DellaVigna (2009) summarizes a number of applications of the beta-delta model from different fields in economics.

- Indicatively, some values for the parameters β, δ reported by DellaVigna (2009):

- $\beta = 0.7, \delta = 0.96$, Laibson et al. (2006)

- $\beta = 0.4, \delta = 0.99$, Paserman (2008)
- $\beta = 0.89, \delta = 0.96$, Paserman (2008)

You can see that present bias is present but afterwards the discounting process is more smooth.

An example

- Let’s see an example with the beta-delta model (this is how quasi-hyperbolic discounting is often called).

- The stream of utilities would be as below.

$$U(c) = u_0 + \beta\delta u_1 + \beta\delta^2 u_2 + \beta\delta^3 u_3 + \cdots = u_0 + \beta \sum_{t=1}^{T} \delta^t u(c_t)$$

An example

- Consider the following table which indicates different investment patterns.
- Assume that the parameters of the discounting function are: $\beta = 0.6, \delta = 0.7$.

- What is the utility of A, B when $t = 0$?
- What is the utility of A, B when $t = 1$? Some time has passed from the initial choice.

	$t = 0$	t =1	t =2
A	0	4	0
B	0	1	5

An example

- When $t = 0$, the utility of each investment pattern will be:

$$U(A) = 0 + 0.6 * 0.7 * 4 + 0.6 * 0.7^2 * 0 = 1.68$$
$$U(B) = 0 + 0.6 * 0.7 * 1 + 0.6 * 0.7^2 * 5 = 0.42 + 1.47 = 1.89$$

So, B is preferred over A.

- When $t = 1$, in the next period investment is re-evaluated and the utility of each investment pattern will be:

$$U(A) = 4 + 0.6 * 0.7 * 0 = 4$$
$$U(B) = 1 + 0.6 * 0.7 * 5 = 2.1$$

So, A is preferred over B.

As time passes and patterns are reconsidered, choices could change.

Naivety

- One question: do you think that people recognise that their choices across time change? Or not?
- This is potentially an important question which could help guide people in their preferences.

- Many people might be completely naïve about their future preferences and could believe that they will be identical with their present preferences. This imply that people practically exhibit present bias in their preferences without being aware of it.
- Naïve agents think they use a constant discount rate across time while in reality they use a hyperbolic approach. If we assume a person's belief about their value of β as b, then it is $\beta < b = 1$.

Sophistication

- What is the opposite that could happen? An individual to understand that their preferences will change across time.

- In this case, people can accurately predict their preferences in the future exactly because they can anticipate their preference. So, people know they exhibit present bias in their choices.

- People who exhibit these traits are called sophisticated.
- For such people it is $\beta = b < 1$.

- How one can be sophisticated? What about being committed to specific actions?

Procrastination

- Recall the SS and LL pair of rewards mentioned earlier between which individuals are asked to choose.
- If these rewards are not positive but are negative instead, then the trade-offs between SS and LL rewards generate another problem: procrastination.
- Assume one starts an assessment which if started early the cost is small but if it's delayed the costs rises (more effort, more stress). Since the cost of SS is in the distant future, people would prefer SS over LL. However, as time passes and SS edges closer, people could switch to LL. Hence, starting the assessment is postponed.
- This is basically the mirror image of the temptation problem we saw earlier.

Procrastination example

- Consider the choice between:

-£100 in 6 years from now

-£200 in 8 years from now

What are the discounting values using the beta-delta model?

Consider $\beta = 0.6, \delta = 0.9$.

$$V(-100) = 0.6(0.9)^6(-100) = -31.9$$

$$V(-200) = 0.6(0.9)^6(-200) = -51.7$$

What would happen as one approaches the SS reward? The choice becomes:

-£100 now

-£200 in 2 years from now

$$V(-100) = -100$$

$$V(-200) = 0.6(0.9)^2(-200) = -97.2$$

$$V(-100) = -100$$
$$V(-200) = 0.6(0.9)^2(-200) = -97.2$$

So, what does this mean?

In the first choice the smaller discounted cost (SS reward) is chosen (-100) since it has the lower cost (-31.9) but as time passes, after 6 years, people would prefer -200 (the LL reward) since it has now lower cost.

In other words, due to procrastination costs are being pushed further into the future and people do not take action in the present.

Explanations about the origin of the discounting process

- Are there any evolutionary explanations about how the discounting process have emerged?

- Robson and Samuelson (2009) claim that aggregate uncertainty (weather fluctuations, food shortage, epidemics, predators) can lead people beyond exponential discounting and directly to present bias and greater impatience.

- Robson and Samuelson stress that their model focuses more on present bias (which they consider a basic feature of evolutionarily-induced intertemporal preferences).
- Their model does not support any preference reversals though.

Ecological interpretation

- Green and Myerson (1996) claim that time discounting of delayed rewards might be explained due to biological reasons.
- Indeed there are evidence that hyperbolic discounting can predict the behaviour of pigeons.
- The idea here is that animals might have to decide whether to get a smaller prey or to continue searching for a larger prey (or whether to travel to a richer but more distant patch or to a closer but leaner patch). This is a rationale of prey and patch models.
- Green and Myerson (1996) claim that discounting the future rewards is an adaptive response to the risks about waiting for future rewards.

Ecological interpretation

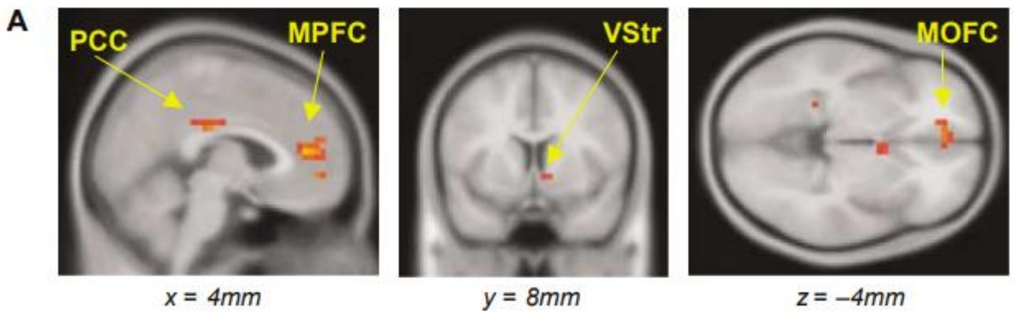
- As delay for an outcome increases, the probability of receiving that outcome could decline and as a result there is a risk the future outcome is not being delivered. For example, with food, a competitor might consume the food first or could force the animal to leave the scene.
- So, it is plausible to assume that risk could increase with the waiting time (the delay).
- Note that this could lead to different discount rates in species adapted for different environments.

- Green and Myerson (1996) show how the hyperbolic model can be associated with foraging models.

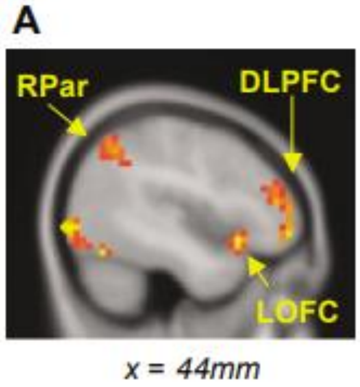
Neuroeconomics approach

- In the newly emerged field of neuroeconomics, there have been some attempts to investigate if time discounting is related to neural systems.
- McClure et al. (2004), used fMRI (Functional Magnetic Resonance Imaging) have investigated such a hypothesis.

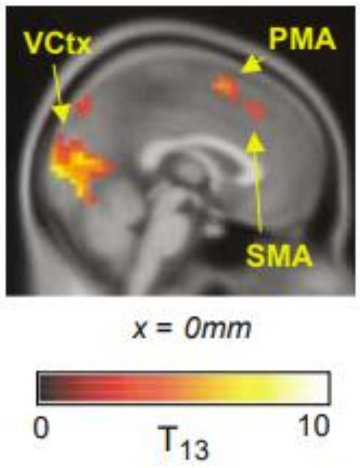
- They found that choices on immediate rewards involve the ventral striatum and prefrontal cortex (β areas).
- In addition, areas like prefrontal cortex and parietal cortex are involved independent of when the rewards become available.
- Also, fronto-parietal activities increase when people choose longer term options.



Brain regions that are preferentially activated for choices in which money is available immediately (β areas).



Brain regions that are active while making choices independent of the delay.



Evidence for declining discount rates

- The economics literature offers many case studies where discount rates are non-constant.

That includes field studies:

- on the attitudes of farmers in Vietnam (Tanaka et al., 2010),
- on the Body Mass Index of Japanese adults (Ikeda et al., 2010),
- on the provision of public goods (Viscusi and Huber, 2006).

Hyperbolic discounting and Body Mass Index (BMI)

- Ikeda et al. (2010) examine how time discounting is related to body weight in a survey among Japanese adults.

- Respondents were asked to choose between a smaller reward available in 2 days versus a larger reward available in 9 days. Additional similar questions were also asked and socio-demographic data was collected.
- They hypothesize that a higher degree of impatience (an index constructed from the answers in the elicitation task) will be positively correlated with the BMI.
- Also, that the hyperbolic discounting index is positively related to BMI.
- Finally, that sign effect index is negatively associated with BMI (here sign effect implies that people who want to avoid the future costs of obesity, have lower BMI).

Implications?

- Ikeda et al. (2010) are able to show that all three hypotheses are confirmed by the data.

- But, what are the policy implications of the study?

- A first suggestion would be to impose a fat tax so that to raise the costs of being obese in the future (exploit the sign effect-BMI relationship).

- Another suggestion would be to counteract policies/adverts that stimulate impulsiveness, perhaps through education and appropriate information.

Time discounting and addiction

- Time discounting has been studied quite extensively in the area of addiction, like smoking, alcohol, opioids and drug addiction (drug dependence in general).
- Kirby et al. (1999) assessed discount rates for heroin addicts in an experiment against non-addicts. The question were based on monetary rewards
- They found that heroin addicts have on average discount rates more than twice compared to non-addicts.
- Kirby et al. (1999) utilize the concept of impulsiveness by Ainslie and Rachlin due to delay discounting where people prefer a smaller sooner reward over a larger later reward but this could change as time passes.

- Note that they use a simple hyperbolic discounting model where the parameter k is indicated as impulsiveness parameter where higher values of k correspond to higher degree of impulsiveness.

The monetary-choice questionnaire was based on one developed by Kirby and Maraković (1996). Participants were presented a fixed set of 27 choices between smaller, immediate rewards (SIRs) and larger, delayed rewards (LDRs). For example, on the first trial participants were asked "Would you prefer $54 today, or $55 in 117 days?" The participant indicated which alternative he or she would prefer to receive by circling the alternative on the questionnaire. The values used in all 27 trials are shown in Table 3. The

Kirby et al.(1999)

- Note that similar findings have been found about delay discounting and cigarette smoking.

- Bickel et al. (1999) report that current smokers discount monetary rewards at a higher rate than ex-smokers and never-smokers.
- Also, hyperbolic discounting offers a better data fit than exponential discounting.

Quantifying the discount rates

Payoff alternative	Payment option A (pays amount below in 1 month)	Payment option B (pays amount below in 3 months)	Annual interest rate (AR)	Annual effective interest rate (AER)	Preferred payment option (Circle A or B)	
1	$500	$501.67	2.00%	2.02%	A	B
2	$500	$502.51	3.00%	3.05%	A	B
3	$500	$503.34	4.00%	4.08%	A	B
4	$500	$504.18	5.00%	5.13%	A	B
5	$500	$506.29	7.50%	7.79%	A	B
6	$500	$508.40	10.00%	10.52%	A	B
7	$500	$510.52	12.50%	13.31%	A	B
8	$500	$512.65	15.00%	16.18%	A	B
9	$500	$514.79	17.50%	19.12%	A	B
10	$500	$516.94	20.00%	22.13%	A	B
11	$500	$521.27	25.00%	28.39%	A	B
12	$500	$530.02	35.00%	41.88%	A	B
13	$500	$543.42	50.00%	64.81%	A	B
14	$500	$566.50	75.00%	111.53%	A	B
15	$500	$590.54	100.00%	171.45%	A	B

In the adjacent experimental design, one has to choose between the options A and B. The choice reveals the discount rate of the participant (Coller and Williams, 1999).

Similar approaches have been used for the elicitation of discount rates in the field and can be used for policy analysis.

Source: Coller and Williams, 1999

Are discount rates constant?

- An obvious question arises here: are discount rates constant? What does the literature has found has found?

- In a comprehensive survey, Frederick et al. (2002) show that there is discounting but there is also large variation in the estimated numbers.

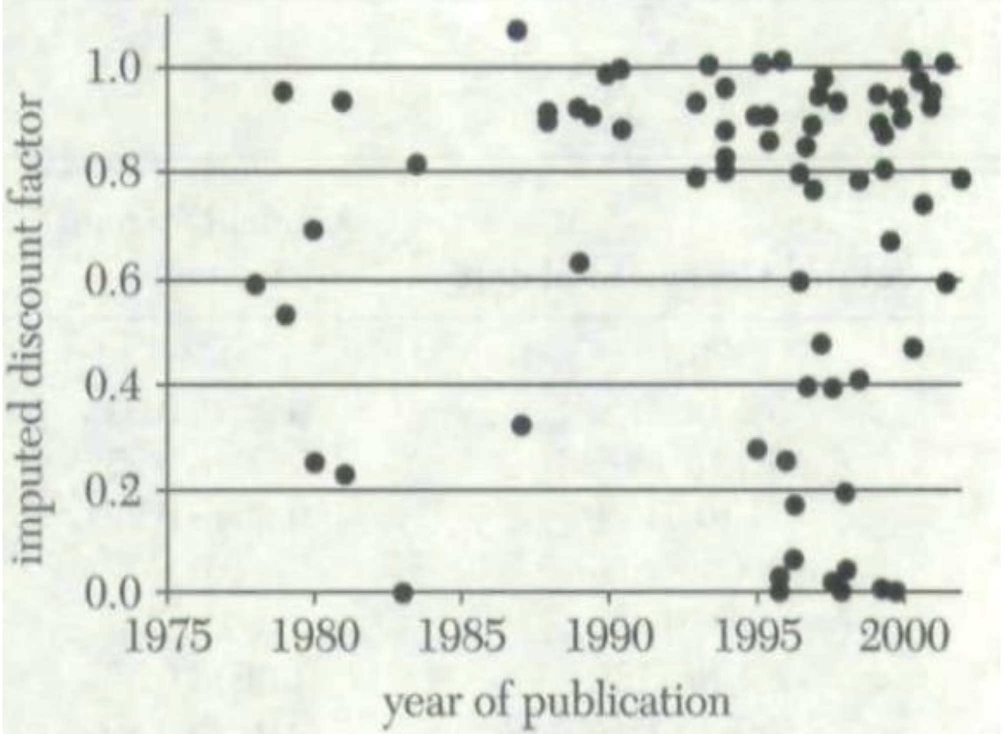


Figure 2. Discount Factor by Year of Study Publication

Source: Frederick et al. (2002)

Methodological issues

- From the previous graph, you can also see that there is no convergence to a specific discount factor, in other words, everything remains open about the "true" discount factor and discount rate.

- Why is this happening? This is an important question which should be answered sufficiently because it is necessary for the validity of the results.

- Let's examine a few reasons why this might be happening.

- The first is that many experiments (especially in psychology) use hypothetical rewards and this might compromise findings.

- The second reason is that if real payments are being used, this might induce present bias (the front end delay however, could help mitigate this problem).

- Another reason is the different elicitation techniques used by different researchers (we will see an example in the next lecture where this will be clearly illustrated).
- Two approaches:

i. a choice task (participants are asked to choose between two different rewards available at different points in time)

ii. a matching task (participants are asked to match a reward available now with a reward available after some time delay).

- Also, the use of multiple time horizons (6 months, 5 years) might be helpful but it might also blur the overall picture.
- Methodological issues are common in economic experiments.

References

- Abellan-Perpiñan, J.M., Bleichrodt, H., and Pinto-Prades, J.L. (2009). The predictive validity of prospect theory versus expected utility in health utility measurement. *Journal of Health Economics*, 28, 1039-1047.
- Ainslie, G. (1992). *Picoeconomics: The strategic interaction of successive motivational states within the person*. Cambridge University Press.
- Coller, M., & Williams, M.B. (1999). Eliciting individual discount rates, *Experimental Economics*, 2, 107-127.
- Frederick, S., Loewenstein, G., & O'Donogue, T. (2002). Time discounting and time preference: A critical review. *Journal of Economic Literature*, 40(2), 351-401.
- Ikeda, S., Kang, M., & Ohtake, F. (2010). Hyperbolic discounting, the sign effect and the body mass index. *Journal of Health Economics*, 29(2), 268-284.
- Laibson, D.I. (1996). Hyperbolic discount functions, undersaving and saving policy. NBER Working Paper No. 5635.
- Loewenstein, G., & Prelec, D. (1992). Anomalies in intertemporal choice: Evidence and an interpretation. *Quarterly Journal of Economics*, 107(2), 573-597.
- Samuelson, P. (1937). A note on measurement of utility. *Review of Economic Studies*, 4(2), 155-161.

- Soman, D. et al. (2005). The psychology of intertemporal discounting: Why are distant events valued differently from proximal ones? *Marketing Letters*, (3-4), 347-360.
- Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge University Press.
- Tanaka, T., Camerer, C.F., & Nguyen, Q. (2010). Risk and time preferences: Linking experimental and household survey data from Vietnam. *American Economic Review*, 100(1), 557-571.
- Thaler, R., & Sefrin, H.M. (1981). An economic theory of self-control. *Journal of Political Economy*, 89(2), 1981.
- Thaler, R., & Benartzi, S. (2004). Save more tomorrow: Using behavioral economics to increase employee savings. *Journal of Political Economy*, 112(S1), S164-S187.