METHODOLOGICAL AND THEORETICAL CONTRIBUTIONS TO THE STUDY OF TIME PREFERENCE

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INTRODUCTION

On a boat trip from Boston to Philadelphia Benjamin Franklin, the American statesman and scientist, found himself in a tangling decision problem when confronted with the delicious smell of fried codfish coming out of the ship kitchen's window. Franklin was a strict vegetarian and his next vegetarian meal was scheduled only within an hour. Should he wait for a decent vegetarian meal or should he take fish and chips immediately? Although he was a vegetarian the impulse of his appetite was too strong for him. He reconsidered his valuations about codfish on the spot: 'The codfish stomach probably is full of small other little fishes. Perhaps codfish was not really the peaceful kind of fish he had always assumed. And, if those fishes eat each other, I might as well eat the codfish immediately'. Benjamin Franklin devoured the fried codfish to his full and immediate satisfaction.

This example illustrates how immediate consumption may be misleadingly attractive. It also shows how subject's choice preferences may change over time. When the tide goes out, our desires often change. In particular, the example illustrates the problem of self control and temptation, which is part and parcel of daily life, but unfortunately not of contemporary economics.

It is often the case that people make decisions about events that occur in different moments in time. Some of these events concern minor issues like eating or not eating some particular food at some particular moment in time. But often these types of decisions are related to major individual concerns. For example, in decisions concerning health subjects choose between an immediate high level of consumption (e.g. drinking) and a poor future, or a moderate level of immediate consumption and prolonged health. Other examples are the decision on when to get pregnant, how much education to obtain and how much to save for retirement. These type of decisions are important not only at an individual but on a global level as well. For example, the next Conference on Global Climate Change in Japan will involve the weighing of the costs and benefits between coal mining and forest clearing today and global warming in a few decades.

The relevance of the component of time for decision making at the individual and global scale has led a group of researchers from a variety of scientific disciplines to focus on a new area of decision making, that is labelled: *choice over time* or *intertemporal choice* [1] [2]. The crucial question in this field is: How much weight do and should people put a future outcomes as compared to present outcomes?

DISCOUNTED UTILITY THEORY

A central phenomenon in the field of intertemporal choice is *positive time preference*. Positive time preference refers to the observation that individuals, man or animal alike-show a systematic preference for receiving a commodity immediately, rather than at some later moment in time. People rather have one apple now than two apples tomorrow; They prefer 'Fl 100 immediately' over 'Fl 110 in 4 weeks' [3]. Indeed, the most well documented observation in the study of intertemporal choice is positive time preference. Individuals like to be paid down on the nail. The tendency to downgrade future rewards or consumption has been observed with pigeons, children and men [4] [5] [6] [7] [8] [9] [10][11][12][13].

Intertemporal choices are often analyzed with the concept of time discounting and the corresponding model of discounted utility. Time discounting implies that the present value of a promise is not the face value of the future outcome, but that it is equivalent to the future outcome discounted by a subjective *discount rate*. Following the discounted utility model subjects can be characterized by the discount rate by which they devalue or discount future outcomes.

Formally, we say that if an amount A of a good will yield utility Ut after a delay of time t, the utility of the outcome at the present (at time 0) will be:

$$U_0 = \frac{U_t}{(1+r)^t} \quad [1]$$

We refer to U_0 as the *present value*. The variable *r* designates the *discount rate*. A decision maker is said to have positive time preference, meaning that outcomes are valued less the more they are delayed, if $r > 0$.

Thus, the discount utility model describes a time-outcome value function that represents the subjective value of an outcome occurring at different moments in time. Subjective value then is a monotonous function of outcome (e.g.

money) and time (e.g. delay). In the intertemporal choice literature the devaluation per unit of time is modelled either by exponential or hyperbolic decay.

Exponential decay is the traditional unit of devaluation [14]. Exponential discounting implies that each unit of time is discounted with a constant fraction. Exponential discounting is mostly used in studying questions on how people *should* weight future outcomes. That is, it is standard in *normative* approaches to intertemporal choice.

Recently, hyperbolic discounting has been frequently suggested as the standard for the *descriptive* approach of intertemporal choice[1][8]. That is, for the study of *how* people *actually* weight future outcomes. Hyperbolic decay implies that the discount rate is not constant but declines more rapidly over time. It is often used to describe subject's changes in preference as time goes by, which cannot be described by the normative approach. That is: they portray positive time preference for the imminent future, but negative time preference for the remote future.

More specifically, people often prefer 'one apple today' to 'two apples tomorrow'; but they prefer 'two apples in a year and a day' over 'one apple in a year'. Similarly, subjects prefer '$100 now' over '$110 in four weeks', but they prefer '$110 in 30 weeks' to '$100 in 26 weeks' [3]. The point is that in contrast to exponential functions, hyperbolic functions cross each other as a function of time, thus being able to account for possible switches in preferences [2].

Roelofsma [15], Roelofsma & Keren[3], Keren & Roelofsma [16] showed that these preference reversals occur because of an immediacy effect. Outcomes occurring later in time are perceived as less certain. As a consequence the imminent future receives a disproportionate weight in the evaluation process. This explains positive time preference for outcomes occurring in the imminent future and negative time preference for outcomes in the remote future.

HYPERBOLIC DISCOUNTING

Hyperbolic discounting has been applied in the theoretical analysis of a variety of 'irrationalities' in intertemporal choice behavior in particular in the study of temptation and self control. Read & Roelofsma [17], for example, have combined the notion of hyperbolic discounting with the notion of 'multiple selves' in a theory of intrapersonal dilemma's that explains subjects problems with temptation and self-control, in particular self defeating behavior. Read & Roelofsma (1999) argue that the phenomenon of the reversal of time preference suggests that subjects behave as if their choices are governed by at least two agents. One of which is concerned with maximizing future rewards (the principal or the planner) and one of which is the agent who is concerned with maximizing imminent rewards (the agent or the doer). The internal conflict between the mutiple selves charachterizes the conflict that is often associated with problems like addiction, procrastination and eating disorders. Figure 1 illustrates hyperbolic discounting and how concept of multiple selves are incorporated in this approach.

Figure 1 represents time-outcome value functions for two promises: the realization of a virtue (Y) and the realization of a vice (X). In the figure, the virtue is the larger reward that comes at a later moment in time. The vice is the smaller reward that comes earlier. For the virtue we can take an event like 'consuming a vegetarian meal' and for the vice 'consuming fish and chips'. In the figure, the y-axis represents the utility of each of the promises and the x-as represents the different moments in time.

As can be seen in the figure the utility function for both promises becomes maximal at the moment of realization, i.e. the moment of receipt. It may be helpful for the reader to stress the point that 'real' time on the x-axis moves from left to right, that is: the realization of the promise gets closer by moving from left to right on the x-axis. More specifically, at the moment of receiving the vice, e.g. fish and chips, the utility of the vice has reached its maximal point. This is depicted as a dotted circle in the figure. The present value of 'receiving the vegetarian meal at a later moment in time', then, can be achieved by drawing a line perpendicular to the x-as at this point. The intersection between this line and the value function of the virtue represents the present value of the virtue. Since Figure 1 shows that utility of the vice at the moment of its receipt is higher then the present value of the virtue meal at that same moment, the subject will choose the vice and consume the fish and chips.

As mentioned earlier hyperbolic value functions cross. This means that a point of indifference can be determined for which the present value of the vice equals the present value of the virtue. This point is represented in Figure 1 as the intersection between the value function of virtues (Y) and vices (X). The point of indifference divides subjects' preferences in distinct intervals. Before the point of indifference subjects will prefer the vegetarian meal. After the point of indifference they will prefer fish and chips. In the figure the planner or principal, who is mainly concerned with long term planning is the self before the crossover point. The doer is the agent that makes the decision. It is the agent that lives for the moment and it is usually the one that prefers the vice.

Multiple self or multiple agent theory was originally developed for multiple person dilemma's [18] but Read & Roelofsma showed that the same theory can also be applied to conflicts of interest within a single person. Each person then is represented as the aggregate of multiple selves, which share conflicting interests, just like multiple selves in an organisation or a society. Accordingly, intrapersonal dilemma's are dilemma's that occur when people make choices that are in the best interest of the self at the moment of choice, but not necessarily for themselves in the long run. By enforcing costs and constraints on selves in the future people may attempt to control their own behavior [17].

METHODOLOGICAL PROBLEMS

The most pervasive methodological problem in the study of intertemporal choice concerns the question of how to measure the discount rate. This applies both for the normative approach where the discount rate is assumed to be fixed per unit of time as well as for the descriptive approach where the discount rate is assumed to decline rapidly over time.

The standard procedure for measuring discount rates is by the use of a method that determines subject's indifference [19][20][21][15] between two outcomes that vary in time and outcome. Accordingly, subjects can be required to provide an indifference value by changing either the outcome or time values for one of the options. For example, subjects can be asked the following question: For what amount will you be indifferent between the following two choice options?

Receive:
$ 100, now or $____ in one year.

Suppose a subject is indifferent between receiving $ 100 now and $ 125 in one year. Then, the discount rate (r) can be calculated by putting these values in formula [I], which will result in r =.25. Indeed, most studies measure the indifference between nominal amounts to derive the subjective discount rate for utility.

However this technique contains a serious methodological flaw. It neglects the important distinction between the discount rate for absolute (nominal) amounts and the discount rate for utility. Observe that the discount function in formula [I] is defined over *utility* and not over nominal amounts. The point is that the relationship between amount and utility is not linear. This fact has been known at least since Bernoulli's famous account on utility in 1738. For example, a decision maker for whom r = .5 will not necessarily be indifferent between $1 in one period and 50¢ in the next period, because the utility from $1 is unlikely to be twice the utility from 50¢. As a results of the non-linear relationship between utility and amount there will always be systematic differences in the discount rate for utility and the discount rate for amounts.

This point is further illustrated in Figure 2. The upperpart of the figure represents indifference between nominal amounts occuring at different moments in time, e.g. $ 100 now and $ 125 in one year. The discount function used for nominal amounts is also presented. As mentioned earlier r=.25. The lower part of the figure represents the corresponding utilities of the amounts and the discount function for utility. For example, let subjects utility functions be represented by the square root of the nominal amount as is often suggested [22]. If subjects are indifferent between receiving '100 now' and '125 in one year' then, with a square root utility function, subjects are indifferent between a commodity with utility of 10 that is received immediately and a commodity with a utility of 11 that is received in one year. However, in terms of utility the discount rate r=.11. This example clearly shows that calculating the discount rate for nominal amounts and assuming it to be the discount rate for utility can be highly misleading.

Surprisingly, however, all attempts by experimentally minded economists and psychologists to measure individual discount rates have involved measuring discount rates for nominal amounts rather than utilities [19] [20][21][15]. We are aware of no previous study in which empirical measures of individual utility functions have been combined with measures of time preference.

The distiction between the discount rate for nominal amounts and the discount rate for utility has important theoretical implications as well. We will discuss them further below. First we will discuss an alternative procedure to measure the discount rate for utility that avoids this serious methodological flaw.

THE PSYCHOPHYSICS OF THE FUTURE

Roelofsma & Read [23] and Roelofsma, Schut and Read [24] have developed a computer programme *Util* for measuring the discount rate for utility. Util integrates empirical measures of time preference and utility. The programme uses a two-stage cross modality matching paradigm, a psychophysical measurement technique. In the first stage, subjects matched numbers to areas (rectangles, circles and squares) of different sizes. Then a unique number-area size function is estimated for each subject. In the second stage, subjects indicated their utility for amount/delay combinations by matching them to areas. Refering back to Figure 2, this would be represented by the values in the two circles at the bottom of the figure. The matched areas are transformed back into a utility scale using the number-area size function. Refering to Figure 2 this is represented in the functions at the left and right. Then, the programme estimates the discount rates for utility. This is represented in the function at the bottom of Figure 2. The programme also measures, the discount rate for amounts, the method used in the earlier studies. As mentioned earlier this is represented in the function at the upper part of Figure 2.

The theoretical foundation for the cross modality matching method that is used in *Util*, is the *Psychophysical Power Law.* Psychophysics have hypothesized for decades that there must be some law that will describe the relationship between the magnitude of an external stimuli (e.g. sound or money) and the magnitude of the internal psychological sensation (e.g.subjective perceived loudness or subjective utility). Stevens Psychophysical Power Law submerged as the established psychophysical answer to this question [34][35][36][37]. Stevens [34] showed that each psychological sensation (Ψ) is a power function of the corresponding stimulus (ϕ), or:

$$y = kf^{b} \qquad \text{[II].}$$

That is, heaviness appears to be a power function of weight, brightness a power function of luminance, visual area is a power function of projected square. Dozens of external stimulus types have shown to relate to their corresponding psychological sensations in terms of a power function. Stevens also suggested that utility would be a power function of nominal amounts of money and Galanter provided the experimental evidence for this assertion, both for monetary and non-monetary goods [22] [25].

In formula II the component *k* is a constant reflecting a scale property and is not particulary interesting. The power exponent β is the important variable since it describes the sense modality and is influenced by experimental variables. Power functions in different sense modalities tend to have different exponents. When applied to the utility of money β is usually < 1.

The interesting point here is that when cross modality matching is used, by matching sensations in one sense modality to sensations arising in another sense modality, the resulting function is another power function. This means that sensations of one sense modality can be adequately used to measure sensations occuring in another. For example, Stevens and Guirao [26] let subjects make subjective judgements of loudness using the length of a line as a measuring aid. CMM has been shown to give very reliable estimates of the real magnitude of the stimulus [37]. Therefor, Roelofsma [15] suggested that CMM may prove to be an important technique for measuring discount utilities, since it eliminates problems with magnitude estimation by generating numbers, a problem that appears particularly salient in the domain of intertemporal choice [29][38].

THEORETICAL IMPLICATIONS

The distinction between the discount rate for utility and the discount rate for money has important theoretical implications as well. Several phenomena in the field can be explained by the systematic differences that occur when using either the one or the other elicitation method.

For example, a general finding in the empirical literature on intertemporal choice is the gain/loss effect[19][20][21][39]. The discount rate for losses appears to be smaller than the discount rate for gains. However, the studies that reported this finding used the discount rate for nominal amounts and not discount rate for utility. The gain/loss effect could, however, occur because the utility function for losses has a different form than the utility function for gains.

Indeed, one of the classic findings in the decision making literature is that losses loom larger that gains [27]. It is often suggested that the utility function for losses is steeper and but more elastic as compared to gains [27] [28].

Roelofsma & Read [35] argued that the gain/loss effect for amount is, in fact, compatible with any possible gain/loss effect for utility. In a series of experiments they measured discount rates gains and losses for a one-year delay. *Util* was used to measure the discount rate for utilities. The traditional method, the discount rate for nominal amounts was also used. Figure 3 illustrates the results of one of the experiments for one year delays in gaining and losing dfl 500, which equals about $250. The figure shows that the discount rates for gains are indeed larger than the discount rate for losses, but only when the discount rate for amounts is measured. When the discount rate for utility is measured, using the *Util* procedure, there are no significant differences between the discount rate for gains and losses. Roelofsma & Read conclude that the gain/loss asymmetry for nominal amounts results from differences in subjects' utility functions for gains and losses.

SUGGESION FOR FURTHER RESEARCH

An important topic for further research is to compare the utility measurement procedure of *Util* with other utility measurement procedures that can eventually be integrated with measures of time preferences. Potential candidates are for example the gamble trade off method [30] and the lottery equiavalent method [31]. This type of research is important not only for further validation of the proposed techniques by Roelofsma et al [24], but also to study an interesting issue related to the phenomena described above: the difference between direct estimation and comparative evaluation.

Methods that use comparative evaluation let subjects compare between options in order to derive a value function. For example, subjects can be asked to indicate for what amount they would be indifferent between receiving $ 100, now or $____ in one year. It is often suggested that in this type of choice subjects are likely to use a comparative choice process, that is: they value the option '100, now' not in absolute terms but only relative to the value of the alternative that is received in one year. [32]. This type of choice process however is open to its own type of bias [34].

Methods that use direct estimates however, like Util, require subjects to match directly the absolute attractiveness, e.g. of '$100, now' with for example the area of a circle. Both methods can be used to measure utility and it would be interesting to what extent they lead to systematic differences.

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Figure 1

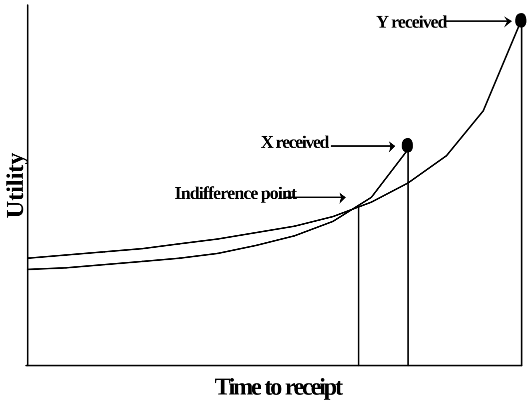

Figure 3

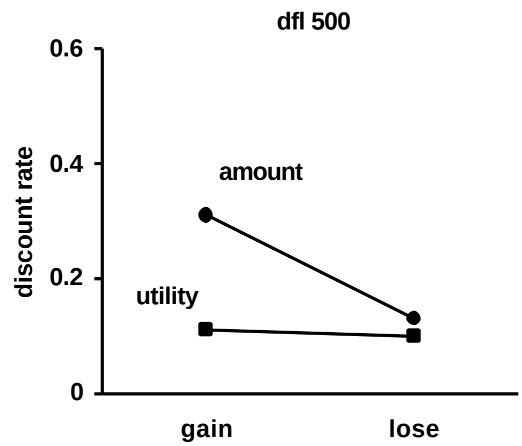

Figure 2.