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Time Discounting and Time Preference: A Critical Review

SHANE FREDERICK, GEORGE LOEWENSTEIN,
and TED O'DONOGHUE[1]

1. *Introduction*

INTERTEMPORAL CHOICES—decisions involving tradeoffs among costs and benefits occurring at different times—are important and ubiquitous. Such decisions not only affect one's health, wealth, and happiness, but, may also, as Adam Smith first recognized, determine the economic prosperity of nations. In this paper, we review empirical research on intertemporal choice, and present an overview of recent theoretical formulations that incorporate insights gained from this research.

Economists' attention to intertemporal choice began early in the history of the discipline. Not long after Adam Smith called attention to the importance of intertemporal choice for the wealth of nations, the Scottish economist John Rae was examining the sociological and psychological determinants of these choices. In section 2, we briefly review the perspectives on intertemporal choice of Rae and nineteenth- and early twentieth-century economists, and describe how these early perspectives interpreted intertemporal choice as the joint product of many conflicting psychological motives.

All of this changed when Paul Samuelson proposed the discounted-utility (DU) model in 1937. Despite Samuelson's manifest reservations about the normative and descriptive validity of the formulation he had proposed, the DU model was accepted almost instantly, not only as a valid normative standard for public policies (e.g., in cost-benefit analyses), but as a descriptively accurate representation of actual behavior. A central assumption of the DU model is that all of the disparate motives underlying intertemporal choice can be condensed into a single parameter—the discount rate. In section 3 we examine this and many other assumptions underlying the DU model. We do not present an axiomatic derivation of the model, but instead focus on those features that highlight the implicit psychological assumptions underlying the model.

[1] Frederick: Sloan School of Management, Massachusetts Institute of Technology. Loewenstein: Department of Social and Decision Sciences, Carnegie Mellon University. O'Donoghue: Department of Economics, Cornell University. We thank Colin Camerer, David Laibson, John McMillan, Drazen Prelec, Daniel Read, Nachum Sicherman, Duncan Simester, and three anonymous referees for useful comments. We thank Cara Barber, Rosa Blackwood, Mandar Oak, and Rosa Stipanovic for research assistance. For financial support, Frederick and Loewenstein thank the Integrated Study of the Human Dimensions of Global Change at Carnegie Mellon University (NSF Grant SBR-9521914), and O'Donoghue thanks the National Science Foundation (Award SES-0078796).

Samuelson's reservations about the descriptive validity of the DU model were justified. Section 4 reviews the growing list of "DU anomalies"—patterns of choice that are inconsistent with the model's theoretical predictions. Virtually every assumption underlying the DU model has been tested and found to be descriptively invalid in at least some situations. Moreover, as we discuss at the end of the section, these anomalies are not anomalies in the sense that they are regarded as errors by the people who commit them. Unlike many of the better-known expected-utility anomalies, the DU anomalies do not necessarily violate any standard or principle that people believe they should uphold.

The insights about intertemporal choice gleaned from this empirical research have led to the proposal of numerous alternative theoretical models, which we review in section 5. Some of these modify the discount function, permitting, for example, declining discount rates or "hyperbolic discounting." Others introduce additional arguments into the utility function, such as the utility of anticipation. Still others depart from the DU model more radically, by including, for instance, systematic mispredictions of future utility. Many of these new theories revive psychological considerations discussed by Rae and other early economists that were extinguished with the adoption of the DU model and its expression of intertemporal preferences in terms of a single parameter.

In section 6, we review attempts to estimate discount rates. While the DU model assumes that people are characterized by a single discount rate, this literature reveals spectacular variation across (and even within) studies. The failure of this research to converge toward any agreed-upon average discount rate stems partly from differences in elicitation procedures. But it also stems from the faulty assumption that the varied considerations that are relevant in intertemporal choices apply equally to different choices and thus that they can all be sensibly represented by a single discount rate.

Throughout the paper, we stress the importance of distinguishing among the varied considerations that underlie intertemporal choices. We distinguish *time discounting* from *time preference*. We use the term *time discounting* broadly to encompass *any* reason for caring less about a future consequence, including factors that diminish the expected utility generated by a future consequence, such as uncertainty or changing tastes. We use the term *time preference* to refer, more specifically, to the preference for immediate utility over delayed utility. In section 7, we push this theme further, by examining whether time preference itself might consist of distinct psychological traits that can be separately analyzed. Section 8 concludes.

2. *Historical Origins of the Discounted Utility Model*

The historical developments that culminated in the formulation of the DU model help to explain the model's limitations. Each of the major figures in the development of the DU model—John Rae, Eugen von Böhm-Bawerk, Irving Fisher, and Paul Samuelson—built upon the theoretical framework of his predecessors, drawing on little more than introspection and personal observation. When the DU model eventually became entrenched as the dominant theoretical framework for modeling intertemporal choice, it was due largely to its simplicity and its resemblance to the familiar compound interest formula, and not as a result of empirical research demonstrating its validity.

Intertemporal choice became firmly established as a distinct topic in 1834, with John Rae's publication of *The Sociological Theory of Capital*. Like Adam Smith, Rae sought to determine why wealth differed among nations. Smith had argued that national wealth was determined by the amount of labor allocated to the production of capital, but Rae recognized that this account was incomplete because it failed to explain the determinants of this allocation. In Rae's view, the missing element was "the effective desire of accumulation"—a psychological factor that differed across countries and determined a society's level of saving and investment.

Along with inventing the topic of intertemporal choice, Rae also produced the first in-depth discussion of the psychological motives underlying intertemporal choice. Rae believed that intertemporal-choice behavior was the joint product of factors that either promoted or limited the effective desire of accumulation. The two main factors that promoted the effective desire of accumulation were the bequest motive ("the prevalence throughout the society of the social and benevolent affections," p. 58) and the propensity to exercise self-restraint ("the extent of the intellectual powers, and the consequent prevalence of habits of reflection, and prudence, in the minds of the members of society," p. 58). One limiting factor was the uncertainty of human life:

> When engaged in safe occupations, and living in healthy countries, men are much more apt to be frugal, than in unhealthy, or hazardous occupations, and in climates pernicious to human life. Sailors and soldiers are prodigals. In the West Indies, New Orleans, the East Indies, the expenditure of the inhabitants is profuse. The same people, coming to reside in the healthy parts of Europe, and not getting into the vortex of extravagant fashion, live economically. War and pestilence have always waste and luxury, among the other evils that follow in their train. (Rae 1834, p. 57)

A second factor that limited the effective desire of accumulation was the excitement produced by the prospect of immediate consumption, and the concomitant discomfort of deferring such available gratifications:

> Such pleasures as may now be enjoyed generally awaken a passion strongly prompting to the partaking of them. The actual presence of the immediate object of desire in the mind by exciting the attention, seems to rouse all the faculties, as it were to fix their view on it, and leads them to a very lively conception of the enjoyments which it offers to their instant possession. (Rae 1834, p. 120)

Among the four factors that Rae identified as the joint determinants of time preference, one can glimpse two fundamentally different views. One, which was later championed by William S. Jevons (1888) and his son, Herbert S. Jevons (1905), assumes that people care only about their immediate utility, and explains farsighted behavior by postulating utility from the anticipation of future consumption. On this view, deferral of gratification will occur only if it produces an increase in "anticipal" utility that more than compensates for the decrease in immediate consumption utility. The second perspective assumes equal treatment of present and future (zero discounting) as the natural baseline for behavior, and attributes the overweighting of the present to the miseries produced by the self-denial required to delay gratification. N. W. Senior, the best-known advocate of this "abstinence" perspective, wrote, "To abstain from the enjoyment which is in our power, or to seek distant rather than immediate results, are among the most painful exertions of the human will" (Senior 1836, p. 60).

The anticipatory-utility and abstinence perspectives share the idea that intertemporal tradeoffs depend on immediate feelings—in one case, the immediate pleasure of anticipation, and in the other, the immediate discomfort of self-denial. The two perspectives, however, explain variability in intertemporal-choice behavior in different ways. The anticipatory-utility perspective attributes variations in intertemporal-choice behavior to differences in people's abilities to imagine the future and to differences in situations that promote or inhibit such mental images. The abstinence perspective, on the other hand, explains variations in intertemporal-choice behavior on the basis of individual and situational differences in the psychological discomfort associated with self-denial. In this view, one should observe high rates of time discounting by people who find it painful to delay gratification, and in situations in which deferral is generally painful—e.g., when one is, as Rae worded it, in the "actual presence of the immediate object of desire."

Eugen von Böhm-Bawerk, the next major figure in the development of the economic perspective on intertemporal choice, added a new motive to the list proposed by Rae, Jevons, and Senior, arguing that humans suffer from a systematic tendency to underestimate future wants:

> It may be that we possess inadequate power to imagine and to abstract, or that we are not willing to put forth the necessary effort, but in any event we limn a more or less incomplete picture of our future wants and especially of the remotely distant ones. And then there are all those wants that never come to mind at all. (Böhm-Bawerk 1889, pp. 268–69)[2]

Böhm-Bawerk's analysis of time preference, like those of his predecessors, was heavily psychological, and much of his voluminous treatise, *Capital and Interest*, was devoted to discussions of the psychological constituents of time preference. However, whereas the early views of Rae, Senior, and Jevons explained intertemporal choices in terms of motives that are uniquely associated with time, Böhm-Bawerk began modeling intertemporal choice in the same terms as other economic tradeoffs—as a "technical" decision about allocating resources (to oneself) over different points in time, much as one would allocate resources between any two competing interests, such as housing and food.

Böhm-Bawerk's treatment of intertemporal choice as an allocation of consumption among time periods was formalized a decade later by the American economist Irving Fisher (1930). Fisher plotted the intertemporal consumption decision on a two-good indifference diagram, with consumption in the current year on the abscissa, and consumption in the following year on the ordinate. This representation made clear that a person's observed (marginal) rate of time preference—the marginal rate of substitution at her chosen consumption bundle—depends on two considerations: time preference and diminishing marginal utility. Many economists have subsequently expressed discomfort with using the term "time preference" to include the effects of differential marginal utility arising from unequal consumption levels between time periods (see in particular Mancur Olson and Martin Bailey 1981). In Fisher's formulation, *pure* time preference can be interpreted as the marginal

[2] In a frequently cited passage from *The Economics of Welfare*, Arthur Pigou (1920) proposed a similar account of time preference, suggesting that it results from a type of cognitive illusion: "our telescopic faculty is defective, and we, therefore, see future pleasures, as it were, on a diminished scale."

rate of substitution on the diagonal, where consumption is equal in both periods.

Fisher's writings, like those of his predecessors, included extensive discussions of the psychological determinants of time preference. Like Böhm-Bawerk, he differentiated "objective factors," such as projected future wealth and risk, from "personal factors." Fisher's list of personal factors included the four described by Rae, "foresight" (the ability to imagine future wants—the inverse of the deficit that Böhm-Bawerk postulated), and "fashion," which Fisher believed to be "of vast importance . . . in its influence both on the rate of interest and on the distribution of wealth itself." (Fisher 1930, p. 88):

> The most fitful of the causes at work is probably fashion. This at the present time acts, on the one hand, to stimulate men to save and become millionaires, and, on the other hand, to stimulate millionaires to live in an ostentatious manner. (Fisher 1930, p. 87)

Hence, in the early part of the twentieth century, "time preference" was viewed as an amalgamation of various intertemporal motives. While the DU model condenses these motives into the discount rate, we will argue that resurrecting these distinct motives is crucial for understanding intertemporal choices.

3. *The Discounted Utility Model*

In 1937, Paul Samuelson introduced the DU model in a five-page article titled "A Note on Measurement of Utility." Samuelson's paper was intended to offer a generalized model of intertemporal choice that was applicable to multiple time periods (Fisher's graphical indifference-curve analysis was difficult to extend to more than two time periods) and to make the point that representing intertemporal tradeoffs required a cardinal measure of utility. But in Samuelson's simplified model, all the psychological concerns discussed over the previous century were compressed into a single parameter, the discount rate.

The DU model specifies a decision maker's intertemporal preferences over consumption profiles $(c_t,\ldots,c_T)$. Under the usual assumptions (completeness, transitivity, and continuity), such preferences can be represented by an intertemporal utility function $U^t(c_t,\ldots,c_T)$. The DU model goes further, by assuming that a person's intertemporal utility function can be described by the following special functional form:

$$U^t(c_t,\ldots,c_T) = \sum_{k=0}^{T-t} D(k)u(c_{t+k})$$

$$\text{where } D(k) = \left(\frac{1}{1+\rho}\right)^k.$$

In this formulation, $u(c_{t+k})$ is often interpreted as the person's cardinal instantaneous utility function—her well-being in period $t + k$—and $D(k)$ is often interpreted as the person's discount function—the relative weight she attaches, in period t, to her well-being in period $t+k$. ρ represents the individual's pure rate of time preference (her discount rate), which is meant to reflect the collective effects of the "psychological" motives discussed in section 2.[3]

Samuelson did not endorse the DU model as a normative model of intertemporal choice, noting that "any connection between utility as discussed here and any welfare concept is disavowed" (p. 161). He also made no claims on behalf of its descriptive validity, stressing, "It is completely arbitrary to assume that the individual behaves so as to maximize an integral of the form envisaged in [the DU model]" (p. 159). However, despite Samuelson's manifest

[3] The continuous-time analogue is $U^t(\{c_\tau\}_{\tau\in[t,T]}) = \int_{\tau=t}^{T} e^{-\rho(\tau-t)}u(c_\tau)$. For expositional ease, we shall restrict attention to discrete-time throughout.

reservations, the simplicity and elegance of this formulation was irresistible, and the DU model was rapidly adopted as the framework of choice for analyzing intertemporal decisions.

The DU model received a scarcely needed further boost to its dominance as the standard model of intertemporal choice when Tjalling C. Koopmans (1960) showed that the model could be derived from a superficially plausible set of axioms. Koopmans, like Samuelson, did not argue that the DU model was psychologically or normatively plausible; his goal was only to show that under some well-specified (though arguably unrealistic) circumstances, individuals were logically compelled to possess positive time preference. Producers of a product, however, cannot dictate how the product will be used, and Koopmans' central technical message was largely lost while his axiomatization of the DU model helped to cement its popularity and bolster its perceived legitimacy.

In the remainder of this section, we describe some important features of the DU model as it is commonly used by economists, and briefly comment on the normative and positive validity of these assumptions. These features do not represent an axiom system—they are neither necessary nor sufficient conditions for the DU model—but are intended to highlight the implicit psychological assumptions underlying the model.[4]

3.1 *Integration of New Alternatives with Existing Plans*

A central assumption in most models of intertemporal choice—including the DU model—is that a person evaluates new alternatives by integrating them with her existing plans. To illustrate, consider a person with an existing consumption plan $(c_t,\ldots,c_T)$ who is offered an intertemporal-choice prospect X, which might be something like an option to give up \$5000 today to receive \$10,000 in five years. Integration means that prospect X is not evaluated in isolation, but in light of how it changes the person's aggregate consumption in all future periods. Thus, to evaluate the prospect X, the person must choose what her new consumption path $(c'_t,\ldots,c'_T)$ would be if she were to accept prospect X, and should accept the prospect if $U^t(c'_t,\ldots,c'_T) > U^t(c_t,\ldots,c_T)$.

An alternative way to understand integration is to recognize that intertemporal prospects alter a person's budget set. If the person's initial endowment is E_0, then accepting prospect X would change her endowment to $E_0 \cup X$. Letting $B(E)$ denote the person's budget set given endowment E—i.e., the set of consumption streams that are feasible given endowment E—the DU model says that the person should accept prospect X if:

$$\max_{(c_t,\ldots,c_T)\in B(E_0\cup X)} \sum_{\tau=t}^{T}\left(\frac{1}{1+\rho}\right)^{\tau-t} u(c_\tau) > \max_{(c_t,\ldots,c_T)\in B(E_0)} \sum_{\tau=t}^{T}\left(\frac{1}{1+\rho}\right)^{\tau-t} u(c_\tau).$$

While integration seems normatively compelling, it may be too difficult to actually do. A person may not have well-formed plans about future consumption streams, or be unable (or unwilling) to recompute the new optimal plan every time she makes an intertemporal choice. Some of the evidence we review below supports the plausible presumption that people evaluate the results of intertemporal choices independently of any expectations they have

[4] There are several different axiom systems for the DU model—in addition to Koopmans, see Peter Fishburn (1970), K. J. Lancaster (1963), Richard F. Meyer (1976), and Fishburn and Ariel Rubinstein (1982).

regarding consumption in future time periods.

3.2 *Utility Independence*

The DU model explicitly assumes that the overall value—or "global utility"—of a sequence of outcomes is equal to the (discounted) sum of the utilities in each period. Hence, the distribution of *utility* across time makes no difference beyond that dictated by discounting, which (assuming positive time preference) penalizes utility that is experienced later. The assumption of utility independence has rarely been discussed or challenged, but its implications are far from innocuous. It rules out any kind of preference for patterns of utility over time—e.g., a preference for a flat utility profile over a roller-coaster utility profile with the same discounted utility.[5]

3.3 *Consumption Independence*

The DU model explicitly assumes that a person's well-being in period $t + k$ is independent of her consumption in any other period—i.e., that the marginal rate of substitution between consumption in periods τ and τ' is independent of consumption in period τ''.

Consumption independence is analogous to, but fundamentally different from, the independence axiom of expected-utility theory. In expected-utility theory, the independence axiom specifies that preferences over uncertain prospects are not affected by the consequences that the prospects share—i.e., that the utility of an experienced outcome is unaffected by other outcomes that one might have experienced (but did not). In intertemporal choice, consumption independence says that preferences over consumption profiles are not affected by the nature of consumption in periods in which consumption is identical in the two profiles—i.e., that an outcome's utility is unaffected by outcomes experienced in prior or future periods. For example, consumption independence says that a person's preference between an Italian and Thai restaurant tonight should not depend on whether she had Italian last night, nor whether she expects to have it tomorrow. As the example suggests, and as Samuelson and Koopmans both recognized, there is no compelling rationale for such an assumption. Samuelson (1952, p. 674) noted that, "the amount of wine I drank yesterday and will drink tomorrow can be expected to have effects upon my today's indifference slope between wine and milk." Similarly, Koopmans (1960, p. 292) acknowledged that, "One cannot claim a high degree of realism for [the independence assumption], because there is no clear reason why complementarity of goods could not extend over more than one time period."

3.4 *Stationary Instantaneous Utility*

When applying the DU model to specific problems, it is often assumed that the cardinal instantaneous utility function $u(c_\tau)$ is constant across time, so that the well-being generated by any activity is the same in different periods. Most economists would acknowledge that stationarity of the instantaneous utility function is not sensible in many situations, because people's preferences do, in fact, change over time in predictable

[5] "Utility independence" has meaning only if one literally interprets $u(c_{t+k})$ as well-being experienced in period $t + k$. We believe that this is, in fact, the common interpretation. For a model that relaxes the assumption of utility independence, see Benjamin Hermalin and Alice Isen (2000), who consider a model in which well-being in period t depends on well-being in period $t - 1$—i.e., they assume $u_t = u(c_t, u_{t-1})$. See also Daniel Kahneman, Peter Wakker, and Rakesh Sarin (1997) who propose a set of axioms that would justify an assumption of additive separability in instantaneous utility.

and unpredictable ways. Though this unrealistic assumption is often retained for analytical convenience, it becomes less defensible as economists gain insight into how tastes change over time (see Loewenstein and Angner, forthcoming, for a discussion of different sources of preference change).[6]

3.5 *Independence of Discounting from Consumption*

The DU model assumes that the discount function is invariant across all forms of consumption. This feature is crucial to the notion of *time* preference. If people discount utility from different sources at different rates, then the notion of a unitary time preference is meaningless. Instead we would need to label time preference according to the object being delayed—"banana time preference," "vacation time preference," and so on. In section 7, we discuss in more detail the validity of the assumption that the same rate of time preference applies to all forms of consumption.

3.6 *Constant Discounting and Time Consistency*

Any discount function can be written in the form $D(k) = \Pi_{n=0}^{k-1}\left(\frac{1}{1+\rho_n}\right)$, where ρ_n represents the per-period discount rate for period n—that is, the discount rate applied between periods n and $n + 1$. Hence, by assuming that the discount function takes the form $D(k)=\left(\frac{1}{1+\rho}\right)^k$, the DU model assumes a constant per-period discount rate ($\rho_n = \rho$ for all n).[7]

Constant discounting entails an evenhandedness in the way a person evaluates time. It means that delaying or accelerating two dated outcomes by a common amount should not change preferences between the outcomes—if in period t a person prefers X at τ to Y at $\tau + d$ for *some* τ, then in period t she must prefer X at τ to Y at $\tau + d$ for *all* τ. The assumption of constant discounting permits a person's time preference to be summarized as a single discount *rate*. If constant discounting does not hold, then characterizing one's time preference requires the specification of an entire discount *function*.

Constant discounting implies that a person's intertemporal preferences are *time-consistent*, which means that later preferences "confirm" earlier preferences. Formally, a person's preferences are time-consistent if, for any two consumption profiles $(c_t,\ldots,c_T)$ and $(c'_t,\ldots,c'_T)$, with $c_t = c'_t$, $U^t(c_t,c_{t+1},\ldots,c_T) \geq U^t(c'_t,c'_{t+1},\ldots,c'_T)$ if and only if $U^{t+1}(c_{t+1},\ldots,c_T) \geq U^{t+1}(c'_{t+1},\ldots,c'_T)$.[8] For an interesting discussion that questions the normative validity of constant discounting, see Martin Albrecht and Martin Weber (1995).

3.7 *Diminishing Marginal Utility and Positive Time Preference*

While not core features of the DU model, virtually all analyses of intertemporal choice assume both diminishing

[6] As we discuss in section 5, endogenous preference changes, due to things such as habit formation or reference dependence, are best understood in terms of consumption interdependence and not nonstationary utility. In some situations, nonstationarities clearly play an important role in behavior—e.g., Steven Suranovic, Robert Goldfarb, and Thomas Leonard (1999), and O'Donoghue and Mathew Rabin (1999a; 2000) discuss the importance of nonstationarities in the realm of addictive behavior.

[7] An alternative but equivalent definition of constant discounting is that $D(k)/D(k+1)$ is independent of k.

[8] Constant discounting implies time-consistent preferences only under the ancillary assumption of stationary discounting, for which the discount function $D(k)$ is the same in all periods. As a counterexample, if the period-t discount function is $D_t(k)=\left(\frac{1}{1+\rho}\right)^k$ while the period-$t+1$ discount function is $D_{t+1}(k) = \left(\frac{1}{1+\rho'}\right)^k$ for some $\rho' \neq \rho$, then the person exhibits constant discounting at both dates t and $t + 1$, but nonetheless has time-inconsistent preferences.

marginal utility (that the instantaneous utility function $u(c_t)$ is concave) and positive time preference (that the discount rate ρ is positive).[9] These two assumptions create opposing forces in intertemporal choice: diminishing marginal utility motivates a person to spread consumption over time, while positive time preference motivates a person to concentrate consumption in the present.

Since people do, in fact, spread consumption over time, the assumption of diminishing marginal utility (or some other property that has the same effect) seems strongly justified. The assumption of positive time preference, on the other hand, is more questionable. Several researchers have argued for positive time preference on logical grounds (Jack Hirshleifer 1970; Koopmans 1960; Koopmans, Peter A. Diamond, and Richard E. Williamson 1964; Olson and Bailey 1981). The gist of their arguments is that a zero or negative time preference, combined with a positive real rate of return on saving, would command the infinite deferral of all consumption.[10] But this conclusion assumes, unrealistically, that individuals have infinite life-spans and linear (or weakly concave) utility functions. Nevertheless, in econometric analyses of savings and intertemporal substitution, positive time preference is sometimes treated as an identifying restriction whose violation is interpreted as evidence of misspecification.

The most compelling argument supporting the logic of positive time preference was made by Derek Parfit (1971; 1976; 1982), who contends that there is no enduring self or "I" over time to which all future utility can be ascribed, and that a diminution in psychological connections gives our descendent future selves the status of other people—making that utility less than fully "ours" and giving us a reason to count it less:[11]

> We care less about our further future . . . because we know that less of what we are now—less, say, of our present hopes or plans, loves or ideals—will survive into the further future . . . [if] what matters holds to a lesser degree, it cannot be irrational to care less. (Parfit 1971, p. 99)

Parfit's claims are normative, not descriptive. He is not attempting to explain or predict people's intertemporal choices, but is arguing that conclusions about the rationality of time preference must be grounded in a correct view of personal identity. However, if this is the only compelling normative rationale for time discounting, it would be instructive to test for a positive relation between observed time discounting and changing identity. Frederick (2002) conducted the only study of this type,

[9] Discounting is not inherent to the DU model, because the model could be applied with $\rho \leq 0$. However, the inclusion of ρ in the model strongly implies that it may take a value other than zero, and the name *discount rate* certainly suggests that it is greater than zero.

[10] In the context of intergenerational choice, Koopmans (1967) called this result the *paradox of the indefinitely postponed splurge*. See also Kenneth J. Arrow (1983), S. Chakravarty (1962), and Robert M. Solow (1974).

[11] As noted by Frederick (2002), there is much disagreement about the nature of Parfit's claim. In her review of the philosophical literature, Jennifer Whiting (1986, p. 549) identifies four different interpretations: (1) the *strong absolute claim*: that it is irrational for someone to care about their future welfare, (2) the *weak absolute claim*: that there is no rational requirement to care about one's future welfare, (3) the *strong comparative claim*: that it is irrational to care more about one's own future welfare than about the welfare of any other person, and (4) the *weak comparative claim*: that one is not rationally required to care more about their future welfare than about the welfare of any other person. We believe that all of these interpretations are too strong, and that Parfit endorses only a weaker version of the weak absolute claim. That is, he claims only that one is not rationally required to care about one's future welfare to a degree that exceeds the degree of psychological connectedness that obtains between one's current self and one's future self.

and found no relation between monetary discount rates (as imputed from procedures such as "I would be indifferent between \$100 tomorrow and \$____ in five years") and self-perceived stability of identity (as defined by the following similarity ratings: "Compared to now, how similar were you five years ago [will you be five years from now]?"), nor did he find any relation between such monetary discount rates and the presumed correlates of identity stability (e.g., the extent to which people agree with the statement "I am still embarrassed by stupid things I did a long time ago").

4. *DU Anomalies*

Over the last two decades, empirical research on intertemporal choice has documented various inadequacies of the DU model as a descriptive model of behavior. First, empirically observed discount rates are not constant over time, but appear to decline—a pattern often referred to as hyperbolic discounting. Furthermore, even for a given delay, discount rates vary across different types of intertemporal choices: gains are discounted more than losses, small amounts more than large amounts, and explicit sequences of multiple outcomes are discounted differently than outcomes considered singly.

4.1 *Hyperbolic Discounting*

The best documented DU anomaly is hyperbolic discounting. The term "hyperbolic discounting" is often used to mean, in our terminology, that a person has a declining rate of time preference (in our notation, ρ_n is declining in n), and we adopt this meaning here. Several results are usually interpreted as evidence for hyperbolic discounting. First, when subjects are asked to compare a smaller-sooner reward to a larger-later reward (see section 6 for a description of these procedures), the implicit discount rate over longer time horizons is lower than the implicit discount rate over shorter time horizons. For example, Richard Thaler (1981) asked subjects to specify the amount of money they would require in [one month/one year/ten years] to make them indifferent to receiving \$15 now. The median responses [\$20/\$50/\$100] imply an average (annual) discount rate of 345 percent over a one-month horizon, 120 percent over a one-year horizon, and 19 percent over a ten-year horizon.[12] Other researchers have found a similar pattern (Uri Benzion, Amnon Rapoport, and Joseph Yagil 1989; Gretchen B. Chapman 1996; Chapman and Arthur S. Elstein 1995; John L. Pender 1996; Daniel A. Redelmeier and Daniel N. Heller 1993).

Second, when mathematical functions are explicitly fit to such data, a hyperbolic functional form, which imposes declining discount rates, fits the data better than the exponential functional form, which imposes constant discount rates (Kris N. Kirby 1997; Kirby and Nino Marakovic 1995; Joel Myerson and Leonard Green 1995; Howard Rachlin, Andres Raineri, and David Cross 1991).[13]

Third, researchers have shown that

[12] That is, $\$15 = \$20*(e^{-(3.45)(1/12)}) = \$50*(e^{-(1.20)(1)}) = \$100*(e^{-(0.19)(10)})$. While most empirical studies report average discount rates over a given horizon, it is sometimes more useful to discuss average "per-period" discount rates. Framed in these terms, Thaler's results imply an average (annual) discount rate of 345 percent between now and one month from now, 100 percent between one month from now and one year from now, and 7.7 percent between one year from now and ten years from now. That is, $\$15 = \$20*(e^{-(3.45)(1/12)}) = \$50*(e^{-(3.45)(1/12)}\, e^{-(1.00)(11/12)}) = \$100*(e^{-(3.45)(1/12)}\, e^{-(1.00)(11/12)} e^{-(0.077)(9)})$.

[13] Several hyperbolic functional forms have been proposed: George Ainslie (1975) suggested the function $D(t) = 1/t$, Richard Herrnstein (1981) and James Mazur (1987) suggested $D(t) = 1/(1 + \alpha t)$, and George Loewenstein and Drazen Prelec (1992) suggested $D(t) = 1/(1 + \alpha t)^{\beta/\alpha}$.

preferences between two delayed rewards can reverse in favor of the more proximate reward as the time to both rewards diminishes—e.g., someone may prefer $110 in 31 days over $100 in 30 days, but also prefer $100 now over $110 tomorrow. Such "preference reversals" have been observed both in humans (Green, Nathaniel Fristoe, and Myerson 1994; Kirby and Herrnstein 1995; Andrew Millar and Douglas Navarick 1984; Jay Solnick et al. 1980) and in pigeons (Ainslie and Herrnstein 1981; Green et al. 1981).[14]

Fourth, the pattern of declining discount rates suggested by the studies above is also evident *across* studies. In section 6, we summarize studies that estimate discount rates. Figure 1a plots the average estimated discount factor (= 1/(1 + discount rate)) from each of these studies against the average time horizon for that study.[15] As the regression line reflects, the estimated discount factor increases with the time horizon, which means that the discount rate declines. We note, however, that after excluding studies with very short time horizons (one year or less) from the analysis (see figure 1b), there is no evidence that discount rates continue to decline. In fact, after excluding the studies with short time horizons, the correlation between time horizon and discount factor is almost exactly zero (–0.0026).

Although the collective evidence outlined above seems overwhelmingly to support hyperbolic discounting, a recent study by Daniel Read (2001) points out that the most common type of evidence—the finding that implicit discount rates decrease with the time horizon—could also be explained by "subadditive discounting," which means the total amount of discounting over a temporal interval increases as the interval is more finely partitioned.[16] To demonstrate subadditive discounting and distinguish it from hyperbolic discounting, Read elicited discount rates for a two-year (24-month) interval and for its three constituent intervals, an eight-month interval beginning at the same time, an eight-month interval beginning eight months later, and an eight-month interval beginning sixteen months later. He found that the average discount rate for the 24-month interval was lower than the compounded average discount rate over the three eight-month subintervals—a result predicted by subadditive discounting but not predicted by hyperbolic discounting (or any type of discount function, for that matter). Moreover, there was no evidence that discount rates declined with time, as the discount rates for the three eight-month intervals were approximately equal. Similar empirical results were found earlier by J. H. Holcomb and P. S. Nelson (1992),

[14] These studies all demonstrate preference reversals in the synchronic sense—subjects simultaneously prefer $100 now over $110 tomorrow and prefer $110 in 31 days over $100 in 30 days, which is consistent with hyperbolic discounting. But there seems to be an implicit belief that such preference reversals would also hold in the diachronic sense—that if subjects who currently prefer $110 in 31 days over $100 in 30 days were brought back to the lab thirty days later, they would prefer $100 at that time over $110 one day later. Under the assumption of stationary discounting (as discussed in footnote 8), synchronic preference reversals imply diachronic preference reversals. To the extent that subjects anticipate diachronic reversals and want to avoid them, evidence of a preference for commitment could also be interpreted as evidence for hyperbolic discounting (we discuss this issue more in section 5.1.1).

[15] In some cases, the discount rates were computed from the median respondent. In other cases, the mean discount rate was used.

[16] Read's proposal that discounting is subadditive is compatible with analogous results in other domains. For example, Amos Tversky and Derek Koehler (1994) found that the total probability assigned to an event increases the more finely the event is partitioned—e.g., the probability of "death by accident" is judged to be more likely if one separately elicits the probability of "death by fire," "death by drowning," "death by falling," etc.

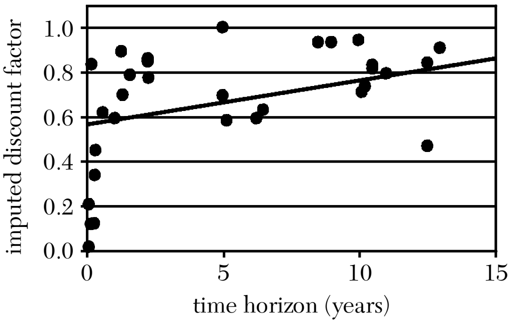

Figure 1a. Discount Factor as a Function of Time Horizon (all studies)

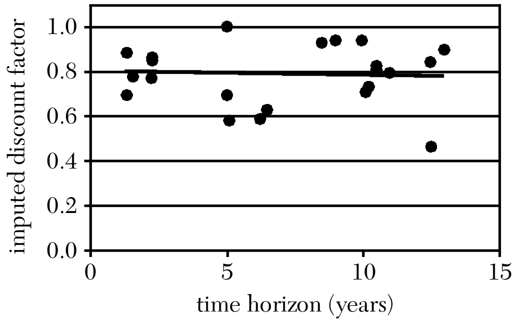

Figure 1b. Discount Factor as a Function of Time Horizon (studies with avg. horizons > 1 year)

although they did not interpret their results the same way.

If Read is correct about subadditive discounting, its main implication for economic applications may be to provide an alternative psychological underpinning for using a hyperbolic discount function, because most intertemporal decisions are based primarily on discounting from the present.[17]

[17] A few studies have actually found *increasing* discount rates. Frederick (1999) asked 228 respondents to imagine that they worked at a job that consisted of both pleasant work ("good days") and unpleasant work ("bad days") and to equate the attractiveness of having additional good days this year or in a future year. On average, respondents were indifferent between 20 extra good days this year, 21 the following year, or 40 in five years, implying a one-year discount rate of 5 percent and a five-year discount rate of 15 percent. A possible explanation is that a desire for improvement is evoked more strongly for two successive years (this year and next) than for two separated years (this year and five years hence). Rubinstein (2000) asked students in a political science class to choose between the following two payment sequences:

	March 1	June 1	Sept 1	Nov 1
A:	$997	$997	$997	$997
	April 1	July1	Oct 1	Dec 1
B:	$1000	$1000	$1000	$1000

Then, two weeks later, he asked them to choose between $997 on November 1 and $1000 on December 1. Fifty-four percent of respondents preferred $997 in November to $1000 in December, but only 34 percent preferred sequence A to sequence B. These two results suggest increasing discount rates. To explain them Rubinstein speculated that the three more proximate additional elements may have masked the differences in the timing of the sequence of dated amounts, while making the differences in amounts more salient.

4.2 *Other DU Anomalies*

The DU model not only dictates that the discount rate should be constant for all time periods; it also assumes that the discount rate should be the same for all types of goods and all categories of intertemporal decisions. There are several empirical regularities that appear to contradict this assumption, namely: (1) gains are discounted more than losses; (2) small amounts are discounted more than large amounts; (3) greater discounting is shown to avoid delay of a good than to expedite its receipt; (4) in choices over sequences of outcomes, improving sequences are often preferred to declining sequences though positive time preference dictates the opposite; and (5) in choices over sequences, violations of independence are pervasive, and people seem to prefer spreading consumption over time in a way that diminishing marginal utility alone cannot explain.

4.2.1 *The "Sign Effect" (gains are discounted more than losses)*

Many studies have concluded that gains are discounted at a higher rate than losses. For instance, Thaler (1981) asked subjects to imagine they had received a traffic ticket that could be paid either now or later and to state how much they would be willing to pay if payment could be delayed (by three months, one year, or three years). The discount rates imputed from these answers were much lower than the discount rates imputed from comparable questions about monetary gains. This pattern is prevalent in the literature. Indeed, in many studies, a substantial proportion of subjects prefer to incur a loss immediately rather than delay it (Benzion, Rapoport, and Yagil 1989; Loewenstein 1987; L. D. MacKeigan et al. 1993; Walter Mischel, Joan Grusec, and John C. Masters 1969; Redelmeier and Heller 1993; J. Frank Yates and Royce A. Watts 1975).

4.2.2 *The "Magnitude Effect" (small outcomes are discounted more than large ones)*

Most studies that vary outcome size have found that large outcomes are discounted at a lower rate than small ones (Ainslie and Varda Haendel 1983; Benzion, Rapoport, and Yagil 1989; Green, Fristoe, and Myerson 1994; Green, Astrid Fry, and Myerson 1994; Holcomb and Nelson 1992; Kirby 1997; Kirby and Marakovic 1995; Kirby, Nancy Petry and Warren Bickel 1999; Loewenstein 1987; Raineri and Rachlin 1993; Marjorie K. Shelley 1993; Thaler 1981). In Thaler's (1981) study, for example, respondents were, on average, indifferent between \$15 immediately and \$60 in a year, \$250 immediately and \$350 in a year, and \$3000 immediately and \$4000 in a year, implying discount rates of 139 percent, 34 percent, and 29 percent, respectively.

4.2.3 *The "Delay-Speedup" Asymmetry*

Loewenstein (1988) demonstrated that imputed discount rates can be dramatically affected by whether the change in delivery time of an outcome is framed as an acceleration or a delay from some temporal reference point. For example, respondents who didn't expect to receive a VCR for another year would pay an average of \$54 to receive it immediately, but those who thought they would receive it immediately demanded an average of \$126 to delay its receipt by a year. Benzion, Rapoport, and Yagil (1989) and Shelley (1993) replicated Loewenstein's findings for losses as well as gains (respondents demanded more to expedite payment than they would pay to delay it).

4.2.4 *Preference for Improving Sequences*

In studies of discounting that involve choices between two outcomes—e.g., X at τ vs. Y at τ'—positive discounting is the norm. Research examining preferences over *sequences* of outcomes, however, has generally found that people prefer improving sequences to declining sequences (for an overview, see Ariely and Carmon, in press; Frederick and Loewenstein 2002; Loewenstein and Prelec 1993). For example, Loewenstein and Nachum Sicherman (1991) found that, for an otherwise identical job, most subjects prefer an increasing wage profile to a declining or flat one (see also Robert Frank 1993). Christopher Hsee, Robert P. Abelson, and Peter Salovey (1991) found that an increasing salary sequence was rated as highly as a decreasing sequence that conferred much more money. Carol Varey and Kahneman (1992) found that subjects strongly preferred streams of decreasing discomfort to streams of increasing discomfort, even when the overall sum of discomfort over the interval was otherwise identical. Loewenstein and Prelec (1993) found that respondents who chose between sequences of two or more events (e.g., dinners or vacation trips) on consecutive weekends or consecutive months generally preferred to save the better thing for last. Chapman (2000) presented respondents with hypothetical sequences of headache pain that were matched in terms of total pain that either gradually lessened or gradually increased with time. Sequence durations included one hour, one day, one month, one year, five years, and twenty years. For all sequence durations, the vast majority (from 82 percent to 92 percent) of subjects preferred the sequence of pain that lessened over time. (See also W. T. Ross, Jr. and I. Simonson 1991).

4.2.5 *Violations of Independence and Preference for Spread*

The research on preferences over sequences also reveals strong violations of independence. Consider the following pair of questions from Loewenstein and Prelec (1993):

> Imagine that over the next five weekends you must decide how to spend your Saturday nights. From each pair of sequences of dinners below, circle the one you would prefer. "Fancy French" refers to a dinner at a fancy French restaurant. "Fancy Lobster" refers to an exquisite lobster dinner at a four-star restaurant. Ignore scheduling considerations (e.g., your current plans).

first weekend	second weekend	third weekend	fourth weekend	fifth weekend	
		Option A			
Fancy French	Eat at home	Eat at home	Eat at home	Eat at home	[11%]
		Option B			
Eat at home	Eat at home	Fancy French	Eat at home	Eat at home	[89%]
		Option C			
Fancy French	Eat at home	Eat at home	Eat at home	Fancy Lobster	[49%]
		Option D			
Eat at home	Eat at home	Fancy French	Eat at home	Fancy Lobster	[51%]

As discussed in section 3.3, consumption independence implies that preferences between two consumption profiles should not be affected by the nature of the consumption in periods in which consumption is identical in the two profiles. Thus, anyone preferring profile B to profile A (which share the fifth period "Eat at Home") should also prefer profile D to profile C (which share the fifth period "Fancy Lobster"). As the data reveal, however, many respondents violated this prediction, preferring the fancy French dinner on the third weekend, if that was the only fancy dinner in the profile, but preferring the fancy French dinner on the first weekend if the profile contained another fancy dinner. This result could be explained by the simple desire to spread consumption over time—which, in this context, violates the dubious assumption of independence that the DU model entails.

Loewenstein and Prelec (1993) provide further evidence of such a preference for spread. Subjects were asked to imagine that they were given two coupons for fancy ($100) restaurant dinners, and were asked to indicate when they would use them, ignoring considerations such as holidays, birthdays, and such. Subjects either were told that "you can use the coupons at any time between today and two years from today" or were told nothing about any constraints. Subjects in the two-year constraint condition actually scheduled both dinners at a *later* time than those who faced no explicit constraint—they delayed the first dinner for eight weeks (rather than three) and the second dinner for 31 weeks (rather than thirteen). This counterintuitive result can be explained in terms of a preference for spread if the explicit two-year interval was greater than the implicit time horizon of subjects in the unconstrained group.

4.3 *Are These "Anomalies" Mistakes?*

In other domains of judgment and choice, many of the famous "effects" that have been documented are regarded as errors by the people who commit them. For example, in the "conjunction fallacy" discovered by Tversky and Kahneman (1983), many people will—with some reflection—recognize that a conjunction cannot be more likely than one of its constituents (e.g., that it *can't* be more likely for Linda to be a feminist bank teller than for her to be "just" a bank teller). In contrast, the patterns of preferences that are regarded as "anomalies" in the context of the DU model do not necessarily violate any standard or principle that people believe they should uphold. Even when the choice pattern is pointed out to people, they do not regard themselves as having made a mistake (and probably have not made one!). For example, there is no compelling logic that dictates that one who prefers to delay a French dinner should also prefer to do so when that French dinner will be closely followed by a lobster dinner.

Indeed, it is unclear whether *any* of the DU "anomalies" should be regarded as mistakes. Frederick and Read (2002) found evidence that the magnitude effect is *more* pronounced when subjects evaluate both "small" and "large" amounts than when they evaluate either one. Specifically, the difference in the discount rates between a small amount ($10) and a large amount ($1000) was larger when the two judgments were made in close succession than when they were made separately. Analogous results were obtained for the sign effect, as the differences in discount rates between gains and losses were slightly larger in a within-subjects design, where respondents evaluated delayed gains and delayed losses, than in a between-subjects design where they evaluate only gains or only losses. Since respondents did not attempt to coordinate their responses to conform to DU's postulates when they evaluated rewards of different sizes, it suggests that they consider the different discount rates to be normatively appropriate. Similarly, even after Loewenstein and Sicherman (1991) informed respondents that a decreasing wage profile ($27,000, $26,000, . . . $23,000) would (via appropriate saving and investing) permit strictly more consumption in every period than the corresponding increasing wage profile with an equivalent nominal total ($23,000, $24,000, . . . $27,000), respondents still preferred the increasing sequence. Perhaps they suspected that they could not exercise the required self control to maintain their desired *consumption* sequence, or felt a general leeriness about the significance of a declining wage, either of which could justify that choice. As these examples illustrate, many DU "anomalies" exist as "anomalies" only by reference to a model that was constructed without regard to its descriptive validity, and which has no compelling normative basis.

5. *Alternative Models*

In response to the anomalies just enumerated, and other intertemporal-choice phenomena that are inconsistent with the DU model, a variety of alternate theoretical models have been developed. Some models attempt to achieve greater descriptive realism by relaxing the assumption of constant discounting. Other models incorporate additional considerations into the instantaneous utility function, such as the utility from anticipation. Still others depart from the DU model more radically, by including, for instance, systematic mispredictions of future utility.

5.1 *Models of Hyperbolic Discounting*

In the economics literature, R. H. Strotz (1955–56) was the first to consider alternatives to exponential discounting, seeing "no reason why an individual should have such a special discount function" (p. 172). Moreover, Strotz recognized that for any discount function other than exponential, a person would have time-inconsistent preferences.[18] He proposed two strategies that might be employed by a person who foresees how her preferences will change over time: the "strategy of precommitment" (wherein she commits to some plan of action) and the "strategy of consistent planning" (wherein she chooses her behavior ignoring plans that she knows her future selves will not carry out).[19] While Strotz did not posit any specific alternative functional forms, he did suggest that "special attention" be given to the case of declining discount rates.

Motivated by the evidence discussed in section 4.1, there has been a recent surge of interest among economists in the implications of declining discount rates (beginning with David Laibson 1994, 1997). This literature has used a particularly simple functional form which captures the essence of hyperbolic discounting:

$$D(k) = \begin{cases} 1 & \text{if } h = 0 \\ \beta\delta^k & \text{if } k > 0. \end{cases}$$

This functional form was first introduced by E. S. Phelps and Pollak (1968) to study intergenerational altruism, and was first applied to individual decision making by Jon Elster (1979). It assumes that the per-period discount rate between now and the next period is $\frac{1-\beta\delta}{\beta\delta}$ whereas the per-period discount rate between any two future periods is $\frac{1-\delta}{\delta} < \frac{1-\beta\delta}{\beta\delta}$. Hence, this (β,δ) formulation assumes a declining discount rate between this period and next, but a constant discount rate thereafter. The (β,δ) formulation is highly tractable, and captures many of the *qualitative* implications of hyperbolic discounting.

Laibson and his collaborators have used the (β,δ) formulation to explore the implications of hyperbolic discounting for consumption-saving behavior. Hyperbolic discounting leads a person to consume more than she would like from a prior perspective (or, equivalently, to under-save). Laibson (1997) explores the role of illiquid assets, such as housing, as an imperfect commitment technology, emphasizing how a person could limit overconsumption by tying up her wealth in illiquid assets. Laibson (1998) explores consumption-saving decisions in a world without illiquid assets (or any other commitment technology). These papers describe how hyperbolic discounting might explain some stylized empirical facts, such as the excess comovement of income and consumption, the existence of asset-specific marginal propensities to consume, low levels of precautionary savings, and the correlation of measured levels of patience with age, income, and wealth. Laibson, Andrea Repetto, and Jeremy Tobacman (1998), and George-Marios Angeletos et al. (2001) calibrate models of consumption-saving decisions, using both exponential discounting and (β,δ) hyperbolic discounting. By comparing simulated data to real-world data, they demonstrate how hyperbolic discounting can better explain a variety of empirical observations in the consumption-saving literature. In particular,

[18] Strotz implicitly assumes stationary discounting.

[19] Building on Strotz's strategy of consistent planning, some researchers have addressed the question of whether there exists a consistent path for general non-exponential discount functions. See in particular Robert Pollak (1968), Bezalel Peleg and Menahem Yaari (1973), and Steven Goldman (1980).

Angeletos et al. (2001) describe how hyperbolic discounting can explain the coexistence of high preretirement wealth, low liquid asset holdings (relative to income levels and illiquid asset holdings), and high credit-card debt.

Carolyn Fischer (1999) and O'Donoghue and Rabin (1999c, 2001) have applied (β,δ) preferences to procrastination, where hyperbolic discounting leads a person to put off an onerous activity more than she would like from a prior perspective.[20] O'Donoghue and Rabin (1999c) examine the implications of hyperbolic discounting for contracting when a principal is concerned with combating procrastination by an agent. They show how incentive schemes with "deadlines" may be a useful screening device to distinguish efficient delay from inefficient procrastination. O'Donoghue and Rabin (2001) explore procrastination when a person must not only choose *when* to complete a task, but also *which* task to complete. They show that a person might never carry out a very easy and very good option because they continually *plan* to carry out an even better but more onerous option. For instance, a person might never take half an hour to straighten the shelves in her garage because she persistently plans to take an entire day to do a major cleanup of the entire garage. Extending this logic, they show that providing people with new options might make procrastination more likely. If the person's only option were to straighten the shelves, she might do it in a timely manner; but if the person can either straighten the shelves or do the major cleanup, she now may do nothing. O'Donoghue and Rabin (1999d) apply this logic to retirement planning.

[20] While not framed in terms of hyperbolic discounting, George Akerlof's (1991) model of procrastination is formally equivalent to a hyperbolic model.

O'Donoghue and Rabin (1999a, 2000), Jonathan Gruber and Botond Koszegi (2000), and Juan D. Carrillo (1999) have applied (β,δ) preferences to addiction. These researchers describe how hyperbolic discounting can lead people to overconsume harmful addictive products, and examine the degree of harm caused by such overconsumption. Carrillo and Thomas Mariotti (2000) and Roland Benabou and Jean Tirole (2000) have examined how (β,δ) preferences might influence a person's decision to acquire information. If, for example, a person is deciding whether to embark on a specific research agenda, she may have the option to get feedback from colleagues about its likely fruitfulness. The standard economic model implies that people should always choose to acquire this information if it is free. However, Carrillo and Mariotti show that hyperbolic discounting can lead to "strategic ignorance"—a person with hyperbolic discounting who is worried about withdrawing from an advantageous course of action when the costs become imminent might choose not to acquire free information if doing so increases the risk of bailing out.

5.1.1 *Self Awareness*

A person with time-inconsistent preferences may or may not be aware that her preferences will change over time. Strotz (1955–56) and Pollak (1968) discussed two extreme alternatives. At one extreme, a person could be completely "naïve" and believe that her future preferences will be identical to her current preferences. At the other extreme, a person could be completely "sophisticated" and correctly predict how her preferences will change over time. While casual observation and introspection suggest that people lie somewhere in between these two extremes, behavioral evidence regarding the degree of awareness is quite limited.

One way to identify sophistication is to look for evidence of commitment. Someone who suspects that her preferences will change over time might take steps to eliminate an option that seems inferior now but might tempt her later. For example, someone who currently prefers $110 in 31 days to $100 in 30 days but who suspects that in a month she will prefer $100 immediately to $110 tomorrow, might attempt to eliminate the $100 reward from the later choice set, and thereby bind herself *now* to receive the $110 reward in 31 days. Real-world examples of commitment include "Christmas clubs" or "fat farms."

Perhaps the best empirical demonstration of a preference for commitment was conducted by Dan Ariely and Klaus Wertenbroch (2002). In that study, MIT executive-education students had to write three short papers for a class and were assigned to one of two experimental conditions. In one condition, deadlines for the three papers were imposed by the instructor and were evenly spaced across the semester. In the other condition, each student was allowed to set her own deadlines for each of the three papers. In both conditions, the penalty for delay was 1 percent per day late, regardless of whether the deadline was externally or self-imposed. Although students in the free-choice condition could have made all three papers due at the end of the semester, many did, in fact, choose to impose deadlines on themselves, suggesting that they appreciated the value of commitment. Few students chose evenly spaced deadlines, however, and those who did not performed worse in the course than those with evenly spaced deadlines (whether externally imposed or self-imposed).[21]

O'Donoghue and Rabin (1999b) examine how people's behaviors depend on their sophistication about their own time inconsistency. Some behaviors, such as using illiquid assets for commitment, require some degree of sophistication. Other behaviors, such as overconsumption or procrastination, are more robust to the degree of awareness, though the degree of misbehavior may depend on the degree of sophistication. To understand such effects, O'Donoghue and Rabin (2001) introduce a formal model of *partial naïveté*, in which a person is aware that she will have future self-control problems but underestimates their magnitude. They show that severe procrastination cannot occur under complete sophistication, but can arise even if the person is only a little naïve. For more discussion on self-awareness, see O'Donoghue and Rabin (in press).

The degree of sophistication versus naiveté has important implications for public policy. If people are sufficiently sophisticated about their own self-control problems, providing commitment devices may be beneficial. However, if people are naïve, policies might be better aimed at either educating people about loss of control (making them more sophisticated), or providing incentives for people to use commitment devices, even if they don't recognize the need for them.

[21] A similar "natural" experiment was recently conducted by the Economic and Social Research Council of Great Britain. They recently eliminated submission deadlines and now accept grant proposals on a "rolling" basis (though they are still reviewed only periodically). In response to this policy change, submissions have actually declined by about 15–20 percent (direct correspondence with Chris Caswill at ESRC).

5.2 *Models That Enrich the Instantaneous Utility Function*

Many discounting anomalies, especially those in section 4.2, can be understood as a misspecification of the instantaneous utility function. Similarly, many of the confounds we discuss in section 6 are caused by researchers attributing to the discount rate aspects of preference that are more appropriately considered as arguments in the instantaneous utility function. As a result, alternative models of intertemporal choice have been advanced that add additional arguments, such as utility from anticipation, to the instantaneous utility function.

5.2.1 *Habit-Formation Models*

James Duesenberry (1952) was the first economist to propose the idea of "habit formation"—that the utility from current consumption ("tastes") can be affected by the level of past consumption. This idea was more formally developed by Pollak (1970) and Harl Ryder and Geoffrey Heal (1973). In habit formation models, the period-τ instantaneous utility function takes the form $u(c_\tau;c_{\tau-1},c_{\tau-2},\ldots)$ where $\partial^2 u/\partial c_\tau \partial c_{\tau'} > 0$ for $\tau' < \tau$. For simplicity, most such models assume that all effects of past consumption for current utility enter through a state variable. That is, they assume that period-τ instantaneous utility function takes the form $u(c_\tau;z_\tau)$ where z_τ is a state variable that is increasing in past consumption and $\partial^2/\partial c_\tau \partial z_\tau > 0$. Both Pollak (1970) and Ryder and Heal (1973) assume that z_τ is the exponentially weighted sum of past consumption, or $z_\tau = \sum_{i=1}^{\infty} \gamma^i c_{\tau-i}$.

Although habit formation is often said to induce a preference for an increasing consumption profile, it can, under some circumstances, lead a person to prefer a decreasing or even nonmonotonic consumption profile. The direction of the effect depends on things such as how much one has already consumed (as reflected in the initial habit stock), and, perhaps most importantly, whether current consumption increases or decreases future utility.

In recent years, habit-formation models have been used to analyze a variety of phenomena. Gary Becker and Kevin Murphy (1988) use a habit-formation model to study addictive activities, and in particular to examine the effects of past and future prices on the current consumption of addictive products.[22] Habit formation can help explain asset-pricing anomalies such as the equity-premium puzzle (Andrew Abel 1990; John Campbell and John Cochrane 1999; George M. Constantinides 1990). Incorporating habit formation into business-cycle models can improve their ability to explain movements in asset prices (Urban Jermann 1998; Michele Boldrin, Lawrence Christiano, and Jonas Fisher 2001). Some recent papers have shown that habit formation may help explain other empirical puzzles in macroeconomics as well. Whereas standard growth models assume that high saving rates cause high growth, recent evidence suggests that the causality can run in the opposite direction. Christopher Carroll, Jody Overland, and David Weil (2000) show that, under conditions of habit formation, high growth rates can cause people to save more. Jeffrey Fuhrer (2000) shows how habit formation might explain the recent finding that aggregate spending tends to have a gradual "hump-shaped" response to

[22] For rational-choice models building on Becker and Murphy's framework, see Athanasios Orphanides and David Zervos (1995), Ruqu Wang (1997), and Suranovic, Goldfarb, and Leonard (1999). For addiction models that incorporate hyperbolic discounting, see O'Donoghue and Rabin (1999a, 2000), Gruber and Koszegi (2000), and Carrillo (1999).

various shocks. The key feature of habit formation that drives many of these results is that, after a shock, consumption adjustment is sluggish in the short term but not in the long term.

5.2.2 *Reference-Point Models*

Closely related to, but conceptually distinct from, habit-formation models are models of reference-dependent utility, which incorporate ideas from prospect theory (Kahneman and Tversky 1979; Tversky and Kahneman 1991). According to prospect theory, outcomes are evaluated using a value function defined over departures from a reference point—in our notation, the period-τ instantaneous utility function takes the form $u(c_\tau,r_\tau) = v(c_\tau - r_\tau)$. The reference point, r_τ, might depend on past consumption, expectations, social comparison, status quo, and such. A second feature of prospect theory is that the value function exhibits *loss aversion*—negative departures from one's reference consumption level decrease utility by a greater amount than positive departures increase it. A third feature of prospect theory is that the value function exhibits—*diminishing sensitivity* for both gains and losses, which means that the value function is concave over gains and convex over losses.[23]

Loewenstein and Prelec (1992) applied a specialized version of such a value function to intertemporal choice to explain the magnitude effect, the sign effect, and the delay-speedup asymmetry. They show that if the elasticity of the value function is increasing in the magnitude of outcomes, people will discount smaller magnitudes more than larger magnitudes. Intuitively, the elasticity condition captures the insight that people are responsive to both differences and ratios of reward amounts. It implies that someone who is indifferent between, say, \$10 now and \$20 in a year should prefer \$200 in a year over \$100 now because the larger rewards have a greater difference (and the same ratio). Consequently, even if a person's time preference is actually constant across outcomes, she will be more willing to wait for a fixed proportional increment when rewards are larger, and, thus, her imputed discount rate will be smaller for larger outcomes. Similarly, if the value function for losses is more elastic than the value function for gains, then people will discount gains more than losses. Finally, such a model helps explain the delay-speedup asymmetry (Loewenstein 1988). Shifting consumption in any direction is made less desirable by loss aversion, since one loses consumption in one period and gains it in another. When delaying consumption, loss aversion reinforces time discounting, creating a powerful aversion to delay. When expediting consumption, loss aversion opposes time discounting, reducing the desirability of speedup (and, occasionally, even causing an aversion to it).

Using a reference-dependent model that assumes loss aversion in consumption, David Bowman, Deborah Minehart, and Rabin (1999) predict that "news" about one's (stochastic) future income affects one's consumption growth differently than the standard Permanent Income Hypothesis predicts. According to (the log-linear version of) the Permanent Income Hypothesis, changes in future income should not

[23] Reference-point models sometimes assume there is a direct effect of the consumption level or reference level, so that $u(c_\tau,r_\tau) = v(c_\tau - r_\tau) + w(c_\tau)$ or $u(c_\tau,r_\tau) = v(c_\tau - r_\tau) + w(r_\tau)$. Some habit-formation models could be interpreted as reference-point models, where the state variable z_τ is the reference point. Indeed, many habit-formation models, such as Pollak (1970) and Constantinides (1990), assume instantaneous utility functions of the form $u(c_\tau - z_\tau)$, although they typically assume neither loss aversion nor diminishing sensitivity.

affect the rate of consumption growth. For example, if a person finds out that her permanent income will be lower than she formerly thought, she would reduce her consumption by, say, 10 percent in every period, leaving her consumption growth unchanged. If, however, this person were loss averse in current consumption, she would be unwilling to reduce this year's consumption by 10 percent—forcing her to reduce future consumption by *more* than 10 percent, and thereby reducing the growth rate of her consumption. Two studies by John Shea (1995a,b) support this prediction. Using both aggregate U.S. data and data from teachers' unions (in which wages are set one year in advance), Shea finds that consumption growth responds more strongly to future wage decreases than to future wage increases.

5.2.3 *Models Incorporating Utility from Anticipation*

Some alternative models build on the notion of "anticipal" utility discussed by the elder and younger Jevons. If people derive pleasure not only from current consumption, but also from anticipating future consumption, then current instantaneous utility will depend positively on future consumption—that is, the period-τ instantaneous utility function would take the form $u(c_\tau; c_{\tau+1}, c_{\tau+2}, \ldots)$ where $\partial u / \partial c_{\tau'} > 0$ for $\tau' > \tau$. Loewenstein (1987) advanced a formal model which assumes that a person's instantaneous utility is equal to the utility from consumption in that period plus some function of the discounted utility of consumption in future periods. Specifically, if we let $v(c)$ denote utility from actual consumption, and assume this is the same for all periods, then:

$$u(c_\tau; c_{\tau+1}, c_{\tau+2}, \ldots) = v(c_\tau) + \alpha[\gamma v(c_{\tau+1}) + \gamma^2 v(c_{\tau+2}) + \ldots] \text{ for some } \gamma < 1.$$

Loewenstein describes how utility from anticipation may play a role in many DU anomalies. Because near-term consumption delivers only consumption utility whereas future consumption delivers both consumption utility and anticipatory utility, anticipatory utility provides a reason to prefer improvement and for getting unpleasant outcomes over with quickly instead of delaying them as discounting would predict. It provides a possible explanation for why people discount different goods at different rates, because utility from anticipation creates a downward bias on estimated discount rates, and this downward bias is larger for goods that create more anticipatory utility. If, for instance, dreading future bad outcomes is a stronger emotion than savoring future good outcomes, which seems highly plausible, then utility from anticipation would generate a sign effect.[24]

Finally, anticipatory utility gives rise to a form of time inconsistency that is quite different from that which arises from hyperbolic discounting. Instead of planning to do the farsighted thing (e.g., save money) but subsequently doing the shortsighted thing (splurging), anticipatory utility can cause people to repeatedly plan to consume a good after some delay that permits pleasurable anticipation, but then to delay again for the same reason when the planned moment of consumption arrives.

Loewenstein's model of anticipatory utility applies to deterministic outcomes. In a recent paper, Caplin and Leahy (2001) point out that many anticipatory emotions, such as anxiety or

[24] Waiting for undesirable outcomes is almost always unpleasant, but waiting for desirable outcomes is sometimes pleasurable and sometimes frustrating. Despite the manifest importance for intertemporal choice of these emotions associated with waiting, we are aware of no research that has sought to understand when waiting for desirable outcomes is pleasurable or aversive.

suspense, are driven by uncertainty about the future, and they propose a new model that modifies expected-utility theory to incorporate such anticipatory emotions. They then show that incorporating anxiety into asset-pricing models may help explain the equity premium puzzle and the risk-free rate puzzle, because anxiety creates a taste for risk-free assets and an aversion to risky assets. Like Loewenstein, Caplin and Leahy emphasize how anticipatory utility can lead to time inconsistency. Koszegi (2001) also discusses some implications of anticipatory utility.

5.2.4 *Visceral Influences*

A final alternative model of the utility function incorporates "visceral" influences such as hunger, sexual desire, physical pain, cravings, and such. Loewenstein (1996, 2000b) argues that economics should take more seriously the implications of such transient fluctuations in tastes. Formally, visceral influences mean that the person's instantaneous utility function takes the form $u(c_\tau,d_\tau)$ where d_τ represents the vector of visceral states in period τ. Visceral states are (at least to some extent) endogenous—e.g., a person's current hunger depends on how much she has consumed in previous periods—and therefore lead to consumption interdependence.

Visceral influences have important implications for intertemporal choice because, by increasing the attractiveness of certain goods or activities, they can give rise to behaviors that look extremely impatient or even impulsive. Indeed, for every visceral influence, it is easy to think of one or more associated problems of self-control—hunger and dieting, sexual desire and various "heat-of-the-moment" behaviors, craving and drug addiction, and so on. Visceral influences provide an alternate account of the preference reversals that are typically attributed to hyperbolic time discounting, because the temporal proximity of a reward is one of the cues that can activate appetitive visceral states (see Laibson 2001; Loewenstein 1996). Other cues—such as spatial proximity, the presence of associated smells or sounds, or similarity in current setting to historical consumption sites—may also have such an effect. Thus, research on various types of cues may help to generate new predictions about the specific circumstances (other than temporal proximity) that can trigger myopic behavior.

The fact that visceral states are endogenous introduces issues of state-management (as discussed by Loewenstein 1999, and Laibson 2001 under the rubric of "cue management"). While the model (at least the rational version of it) predicts that a person would want herself to use drugs if she were to experience a sufficiently strong craving, it also predicts that she might want to prevent ever experiencing such a strong craving. Hence, visceral influences can give rise to a preference for commitment in the sense that the person may want to avoid certain situations.

Visceral influences may do more than merely change the instantaneous utility function. First, there is evidence that people don't fully appreciate the effects of visceral influences, and hence may not react optimally to them (Loewenstein 1996, 1999, 2000b). When in a hot state, people tend to exaggerate how long the hot state will persist, and, when in a cold state, people tend to underestimate how much future visceral influences will affect their future behavior. Second, and perhaps more importantly, people often would "prefer" not to respond to an intense visceral factor such as rage, fear, or lust, even at the moment they are succumbing to its influence. A way to understand such effects is to apply the distinction proposed by Kahneman (1994) between "experienced utility," which reflects one's welfare, and "decision utility," which reflects the attractiveness of options as inferred from one's decisions. By increasing the decision utility of certain types of actions more than the experienced utility of those actions, visceral factors may drive a wedge between what people do and what makes them happy. Douglas Bernheim and Antonio Rangel (2001) propose a model of addiction framed in these terms.

5.3 *More "Extreme" Alternative Perspectives*

The alternative models discussed above modify the DU model by altering the discount function or adding additional arguments to the instantaneous utility function. The alternatives discussed next involve more radical departures from the DU model.

5.3.1 *Projection Bias*

In many of the alternative models of utility discussed above, the person's utility from consumption—her tastes—change over time. To properly make intertemporal decisions, a person must correctly predict how her tastes will change. Essentially all economic models of changing tastes assume (as economists typically do) that such predictions are correct—that people have "rational expectations." However, Loewenstein, O'Donoghue, and Rabin (2000) propose that, while people may anticipate the qualitative nature of their changing preferences, they tend to underestimate the magnitude of these changes—a systematic misprediction they label *projection bias*.

Loewenstein, O'Donoghue, and Rabin review a broad array of evidence that demonstrates the prevalence of projection bias, and then model it formally. To illustrate their model, consider projection bias in the realm of habit formation. As discussed above, suppose the period-τ instantaneous utility function takes the form $u(c_\tau;z_\tau)$, where z_τ is a state variable that captures the effects of past consumption. Projection bias arises when a person whose current state is z_t must predict her future utility given future state z_τ. Projection bias implies that the person's prediction $\tilde{u}(c_\tau;z_\tau \mid z_t)$ will lie between her true future utility $u(c_\tau;z_\tau)$ and her utility given her current state $u(c_\tau;z_t)$. A particularly simple functional form is $\tilde{u}(c_\tau;z_\tau \mid z_t) = (1-\alpha)u(c_\tau;z_\tau) + \alpha u(c_\tau z_t)$ for some $\alpha \in [0,1]$.

Projection bias may arise whenever tastes change over time, whether through habit formation, changing reference points, or changes in visceral states. It can have important behavioral and welfare implications. For instance, people may underappreciate the degree to which a present consumption splurge will raise their reference consumption level, and thereby decrease their enjoyment of more modest consumption levels in the future. When intertemporal choices are influenced by projection bias, estimates of time preference may be distorted.

5.3.2 *Mental-Accounting Models*

Some researchers have proposed that people do not treat all money as fungible, but instead assign different types of expenditures to different "mental accounts" (see Thaler 1999 for a recent overview). Such models can give rise to intertemporal behaviors that seem odd when viewed through the lens of the DU model. Thaler (1985), for instance, suggests that small amounts of money are coded as spending money, whereas larger amounts of money are coded as savings, and that a person is more willing to spend out of the former account. This accounting rule would predict that people will behave like spendthrifts for small purchases (e.g., a new pair of shoes), but act more frugally when it comes to large purchases (e.g., a new dining-room table).[25] Shlomo Benartzi and Thaler (1995) suggest that people treat their financial portfolios as a mental account, and emphasize the importance of how often people "evaluate" this account. They argue that if people review their portfolios once a year or so, and if people experience joy or pain from any gains or losses, as assumed in Kahneman and Tversky's (1979) prospect theory, then such "myopic loss aversion" represents a plausible explanation for the equity premium puzzle.

Prelec and Loewenstein (1998) propose another way in which mental accounting might influence intertemporal choice. They posit that payments for consumption confer immediate disutility or "pain of paying," and that people keep mental accounts that link the consumption of a particular item with the payments for it. They also assume that people engage in "prospective accounting." According to prospective accounting, when consuming, people think only about current and future payments; past payments don't cause pain of paying. Likewise, when paying, the pain of paying is buffered only by thoughts of future, but not past, consumption. The model suggests that different ways of financing a purchase can lead to different decisions, even holding the net present value of payments constant. Similarly, a person might have different financing preferences depending on the consumption item (e.g., they should prefer to prepay for a vacation that is consumed all at once vs. a new car that is consumed over many years). The model generates a strong preference for prepayment (except for durables), for getting paid after rather than before doing work, and for fixed-fee pricing schemes with zero marginal costs over pay-as-you-go schemes that tightly couple marginal payments to marginal consumption. The model also suggests that interindividual heterogeneity might arise from differences in the degree to which people experience the pain of paying rather than differences in time preference. On this view, the miser who eschews a fancy restaurant dinner is not doing so because she explicitly considers the delayed costs of the indulgence, but rather because her enjoyment of the dinner would be diminished by the immediate pain of paying for it.

5.3.3 *Choice Bracketing*

One important aspect of mental accounting is that a person makes at most a few choices at any one time, and generally ignores the relation between these choices and other past and future choices. Which choices are considered at the same time is a matter of what Read, Loewenstein, and Rabin (1999) label "choice bracketing." Intertemporal choices, like other choices, can be influenced by the manner in which they are bracketed, because different bracketing can highlight different motives. To illustrate, consider the conflict between impatience and a preference for improvement over time. Loewenstein and Prelec (1993) demonstrate that the relative importance of these two motives can be altered by the way that

[25] While it seems possible that this conceptualization could explain the magnitude effect as well, the magnitude effect is found for very "small" amounts (e.g., between $2 and $20 in Ainslie and Haendel 1983), and for very "large amounts" (e.g., between $10,000 and $1,000,000 in Raineri and Rachlin 1993). It seems highly unlikely that respondents would consistently code the lower amounts as spending and the higher amounts as savings across all of these studies.

choices are bracketed. They asked one group of subjects to choose between having dinner at a fine French restaurant in one month vs. two months. Most subjects chose one month, presumably reflecting impatience. They then asked another group to choose between eating at home in one month followed by eating at the French restaurant in two months vs. eating at the French restaurant in one month followed by eating at home in two months. The majority now wanted the French dinner in two months. For both groups, dinner at home was the most likely alternative to the French dinner, but it was only when the two dinners were expressed as a sequence that the preference for improvement became a basis for decision.

Analyzing how people frame or bracket choices may help illuminate the issue of whether a preference for improvement merely reflects the combined effect of other motives, such as reference dependence or anticipatory utility, or whether it is something unique. Viewed from an integrated decision-making perspective, it perhaps seems natural to conclude that the preference for improvement is derivative of these other concepts, because it is not clear why improvement for its own sake should be valuable. But when viewed from a choice-bracketing perspective, wherein a person must have some choice heuristic for evaluating sequences, it seems possible that improvement may be valued for its own sake. Specifically, a preference-for-improvement choice heuristic may have originated from considerations of reference dependence or anticipatory utility, but a person using this choice heuristic may come to feel that improvement for its own sake has value.[26]

Loewenstein and Prelec (1993) develop a (choice-heuristic) model for how people evaluate choices over sequences. They assume that people consider a sequence's discounted utility, its degree of improvement, and its degree of spread. The key ingredients of the model are "gestalt" definitions for improvement and spread. In other words, they develop a formal measure of the degree of improvement and the degree of spread for any sequence. They show that their model can explain a wide range of sequence anomalies, including observed violations of independence, and that it predicts preferences between sequences much better than other models that incorporate similar numbers of free parameters (even a model with an entirely flexible time discount function).

5.3.4 *Multiple-Self Models*

An influential school of theorists have proposed models that view intertemporal choice as the outcome of a conflict between multiple selves. Most multiple-self models postulate myopic selves who are in conflict with more farsighted ones, and often draw analogies between intertemporal choice and a variety of different models of interpersonal strategic interactions. Some models (e.g., Ainslie and Nick Haslam 1992; Thomas

[26] Thus, to the extent that the preference for improvement reflects a choice heuristic, it should be susceptible to framing or bracketing effects, because what constitutes a sequence is highly subjective, as noted by Loewenstein and Prelec 1993 and by John G. Beebe-Center (1929) several decades earlier:

> *What enables one to decide whether a given set of affective experiences does, or does not, constitute a unitary temporal group*? . . . what of series involving experiences of different modalities— . . . visual and auditory experiences, for instance? . . . And what of such complex events as "arising in the morning" or "eating a good meal" or "enjoying a good book?" (Beebe-Center 1929, p. 67, emphasis added)

C. Schelling 1984; Gordon C. Winston 1980) assume that there are two agents, one myopic and one farsighted, who alternately take control of behavior. The main problem with this approach is that it fails to specify why either type of agent emerges when it does. Furthermore, by characterizing the interaction as a battle between the two agents, these models fail to capture an important asymmetry: farsighted selves often attempt to control the behaviors of myopic selves, but never the reverse. For instance, the farsighted self may pour vodka down the drain to prevent tomorrow's self from drinking it, but the myopic self rarely takes steps to ensure that tomorrow's self will have access to the alcohol he will then crave.

Responding, in part, to this problem, Thaler and Hersh Shefrin (1981) proposed a "planner-doer" model that draws upon principal-agent theory. In their model, a series of myopic "doers," who care only about their own immediate gratification (and have no affinity for future or past doers), interact with a unitary "planner" who cares equally about the present and future. The model focuses on the strategies employed by the planner to control the behavior of the doers. The model highlights the observation, later discussed at length by Loewenstein (1996), that the farsighted perspective is often much more constant than the myopic perspective. For example, people are often consistent in recognizing the need to maintain a diet. Yet they periodically violate their own desired course of action—often recognizing even at the moment of doing so that they are not behaving in their own self-interest.

Yet a third type of multiple-self model draws connections between intertemporal choice and models of multiperson strategic interactions (Elster 1985). The essential insight that these models capture is that, much like cooperation in a social dilemma, self-control often requires the cooperation of a series of temporally situated selves. When one self "defects" by opting for immediate gratification, the consequence can be a kind of unraveling or "falling off the wagon" when subsequent selves follow the precedent.

Few of these multiple-self models have been expressed formally, and even fewer have been used to derive testable implications that go much beyond the intuitions that inspired them in the first place. However, perhaps it is unfair to criticize the models for these shortcomings. These models are probably best viewed as metaphors intended to highlight specific aspects of intertemporal choice. Specifically, multiple-self models have been used to make sense of the wide range of self-control strategies that people use to regulate their own future behavior. Moreover, these models provided much of the inspiration for more recent formal models of sophisticated hyperbolic discounting (following Laibson 1994, 1997).

5.3.5 *Temptation Utility*

Most models of intertemporal choice—indeed, most models of choice in any framework—assume that options not chosen are irrelevant to a person's well-being. In a recent paper, Gul and Pesendorfer (2001) posit that people have "temptation preferences," wherein they experience disutility from not choosing the option that is most enjoyable now. Their theory implies that a person might be better off if some particularly tempting option were not available, even if she doesn't choose that option. As a result, she may be willing to pay in advance to eliminate that option, or in other words, she may have a preference for commitment.

5.3.6 *Conclusion: Combining Insights from Different Models*

Many behavioral models of intertemporal choice focus on a single modification to the DU model and explore the additional realism produced by that single modification. But many empirical phenomena reflect the interaction of multiple phenomena. For instance, a preference for improvement may interact with hyperbolic discounting to produce preferences for U-shaped sequences—e.g., for jobs that offer a signing bonus and a salary that increases gradually over time. As discussed by Loewenstein and Prelec (1993), in the short term, the preference-for-improvement motive is swamped by the high discount rates, but as the discount rate falls over time, the preference-for-improvement motive may gain ascendance and cause a net preference for an increasing payment sequence.

As another example, introducing visceral influences into models of hyperbolic discounting may more fully account for the phenomenology of impulsive choices. Hyperbolic-discounting models predict that people respond especially strongly to immediate costs and benefits, and visceral influences have powerful transient effects on immediate utilities. In combination, the two assumptions could explain a wide range of impulsive choices and other self-control phenomena.

6. *Measuring Time Discounting*

The DU model assumes that a person's time preference can be captured by a single discount rate, ρ. Over the past three decades, there have been many attempts to measure this rate. Some of these estimates are derived from observations of "real-world" behaviors (e.g., the choice between electrical appliances that differ in their initial purchase price and long-run operating costs). Others are derived from experimental elicitation procedures (e.g., respondents' answers to the question "Which would you prefer: \$100 today or \$150 one year from today?"). Table 1 summarizes the implicit discount rates from all studies that we could locate in which discount rates were either directly reported or easily computed from the reported data.

Figure 2 plots the estimated discount factor for each study against the publication date for that study, where the discount factor is $\delta = 1/(1 + \rho)$.[27] This figure reveals three noteworthy observations. First, there is tremendous variability in the estimates (the corresponding implicit annual discount rates range from –6 percent to infinity). Second, in contrast to estimates of physical phenomena such as the speed of light, there is no evidence of methodological progress; the range of estimates is not shrinking over time. Third, high discounting predominates, as most of the data points are well below 1, which represents equal weighting of present and future.

In this section, we provide an overview and critique of this empirical literature with an eye toward understanding these three observations. We first discuss a variety of confounding factors, such as intertemporal arbitrage, uncertainty, and expectations of changing utility functions. These considerations typically are not regarded as legitimate components of time preference *per se*, but they can affect both experimental responses and real-world choices. With these confounding factors in mind, we then review the procedures used to estimate discount rates. This section reiterates our general theme: To truly understand intertemporal choices,

[27] In some cases, the estimates are computed from the median respondent. In other cases, the authors reported the mean discount rate.

TABLE 1
EMPIRICAL ESTIMATES OF DISCOUNT RATES

Study	Type	Good(s)	Real or Hypo?	Elicitation Method
Maital & Maital 1978	experimental	money & coupons	hypo.	choice
Hausman 1979	field	money	real	choice
Gateley 1980	field	money	real	choice
Thaler 1981	experimental	money	hypo.	matching
Ainslie & Haendel 1983	experimental	money	real	matching
Houston 1983	experimental	money	hypo.	other
Loewenstein 1987	experimental	money & pain	hypo.	pricing
Moore and Viscusi 1988	field	life years	real	choice
Benzion et al. 1989	experimental	money	hypo.	matching
Viscusi & Moore 1989	field	life years	real	choice
Moore & Viscusi 1990a	field	life years	real	choice
Moore & Viscusi 1990b	field	life years	real	choice
Shelley 1993	experimental	money	hypo.	matching
Redelmeier & Heller 1993	experimental	health	hypo.	rating
Cairns 1994	experimental	money	hypo.	choice
Shelley 1994	experimental	money	hypo.	rating
Chapman & Elstein 1995	experimental	money & health	hypo.	matching
Dolan & Gudex 1995	experimental	health	hypo.	other
Dreyfus and Viscusi 1995	field	life years	real	choice
Kirby & Marakovic 1995	experimental	money	real	matching
Chapman 1996	experimental	money & health	hypo.	matching
Kirby & Marakovic 1996	experimental	money	real	choice
Pender 1996	experimental	rice	real	choice
Wahlund & Gunnarson 1996	experimental	money	hypo.	matching
Cairns & van der Pol 1997	experimental	money	hypo.	matching
Green, Myerson & McFadden 1997	experimental	money	hypo.	choice
Johanneson & Johansson 1997	experimental	life years	hypo.	pricing
Kirby 1997	experimental	money	real	pricing
Madden et al. 1997	experimental	money & heroin	hypo.	choice
Chapman & Winquist 1998	experimental	money	hypo.	matching
Holden, Shiferaw & Wik 1998	experimental	money & corn	real	matching
Cairns & van der Pol 1999	experimental	health	hypo.	matching
Chapman, Nelson & Hier 1999	experimental	money & health	hypo.	choice
Coller & Williams 1999	experimental	money	real	choice
Kirby, Petry & Bickel 1999	experimental	money	real	choice
van der Pol & Cairns 1999	experimental	health	hypo.	choice
Chesson & Viscusi 2000	experimental	money	hypo.	matching
Ganiats et al. 2000	experimental	health	hypo.	choice
Hesketh 2000	experimental	money	hypo.	choice
van der Pol & Cairns 2001	experimental	health	hypo.	choice
Warner & Pleeter 2001	field	money	real	choice
Harrison, Lau & Williams 2002	experimental	money	real	choice

TABLE 1 (*Cont.*)

Study	Time Range	Annual Discount Rate(s)	Annual Discount Factor(s)
Maital & Maital 1978	1 year	70%	0.59
Hausman 1979	undefined	5% to 89%	0.95 to 0.53
Gateley 1980	undefined	45% to 300%	0.69 to 0.25
Thaler 1981	3 mos. to 10 yrs.	7% to 345%	0.93 to 0.22
Ainslie & Haendel 1983	undefined	96000% to ∞	0.00
Houston 1983	1 yr. to 20 yrs.	23%	0.81
Loewenstein 1987	immediately to 10 yrs.	–6% to 212%	1.06 to 0.32
Moore and Viscusi 1988	undefined	10% to 12%	0.91 to 0.89
Benzion et al. 1989	6 mos. to 4 yrs.	9% to 60%	0.92 to 0.63
Viscusi & Moore 1989	undefined	11%	0.90
Moore & Viscusi 1990a	undefined	2%	0.98
Moore & Viscusi 1990b	undefined	1% to 14%	0.99 to 0.88
Shelley 1993	6 mos. to 4 yrs.	8% to 27%	0.93 to 0.79
Redelmeier & Heller 1993	1 day to 10 yrs.	0%	1.00
Cairns 1994	5 yrs. to 20 yrs.	14% to 25%	0.88 to 0.80
Shelley 1994	6 mos. to 2 yrs.	4% to 22%	0.96 to 0.82
Chapman & Elstein 1995	6 mos. to 12 yrs.	11% to 263%	0.90 to 0.28
Dolan & Gudex 1995	1 month to 10 yrs.	0%	1.00
Dreyfus and Viscusi 1995	undefined	11% to 17%	0.90 to 0.85
Kirby & Marakovic 1995	3 days to 29 days	3678% to ∞	0.03 to 0.00
Chapman 1996	1 yr. to 12 yrs.	negative to 300%	1.01 to 0.25
Kirby & Marakovic 1996	6 hours to 70 days	500% to 1500%	0.17 to 0.06
Pender 1996	7 mos. to 2 yrs.	26% to 69%	0.79 to 0.59
Wahlund & Gunnarson 1996	1 month to 1 yr.	18% to 158%	0.85 to 0.39
Cairns & van der Pol 1997	2 yrs. to 19 yrs.	13% to 31%	0.88 to 0.76
Green, Myerson & McFadden 1997	3 mos. to 20 yrs.	6% to 111%	0.94 to 0.47
Johanneson & Johansson 1997	6 yrs. to 57 yrs.	0% to 3%	0.97
Kirby 1997	1 day to 1 month	159% to 5747%	0.39 to 0.02
Madden et al. 1997	1 week to 25 yrs.	8% to ∞	0.93 to 0.00
Chapman & Winquist 1998	3 months	426% to 2189%	0.19 to 0.04
Holden, Shiferaw & Wik 1998	1 yr.	28% to 147%	0.78 to 0.40
Cairns & van der Pol 1999	4 yrs. to 16 yrs.	6%	0.94
Chapman, Nelson & Hier 1999	1 month to 6 mos.	13% to 19000%	0.88 to 0.01
Coller & Williams 1999	1 month to 3 mos.	15% to 25%	0.87 to 0.80
Kirby, Petry & Bickel 1999	7 days to 186 days	50% to 55700%	0.67 to 0.00
van der Pol & Cairns 1999	5 yrs. to 13 yrs.	7%	0.93
Chesson & Viscusi 2000	1 year to 25 yrs.	11%	0.90
Ganiats et al. 2000	6 mos. to 20 yrs.	negative to 116%	1.01 to 0.46
Hesketh 2000	6 mos. to 4 yrs.	4% to 36%	0.96 to 0.74
van der Pol & Cairns 2001	2 yrs. to 15 yrs.	6% to 9%	0.94 to 0.92
Warner & Pleeter 2001	immediately to 22 yrs.	0% to 71%	0 to 0.58
Harrison, Lau & Williams 2002	1 month to 37 mos.	28%	0.78

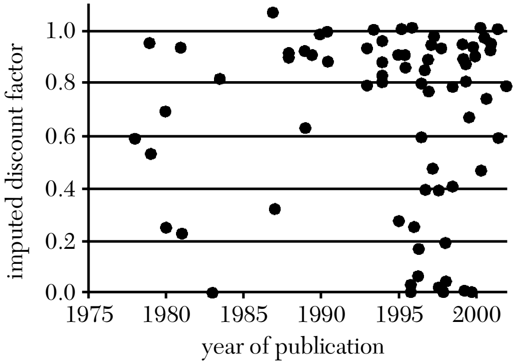

Figure 2. Discount Factor by Year of Study Publication

one must recognize the influence of many considerations besides pure time preference.

6.1 *Confounding Factors*

A wide variety of procedures have been used to estimate discount rates, but most apply the same basic approach. Some actual or reported intertemporal preference is observed, and researchers then compute the discount rate that this preference implies, using a "financial" or net present value (NPV) calculation. For instance, if a person demonstrates indifference between 100 widgets now and 120 widgets in one year, the implicit (annual) discount rate, ρ, would be 20 percent, because that value would satisfy the equation $100 = (1/(1 + \rho))120$. Similarly, if a person is indifferent between an inefficient low-cost appliance and a more efficient one that costs \$100 extra but saves \$20 a year in electricity over the next ten years, the implicit discount rate, ρ, would equal 15.1 percent, because that value would satisfy the equation $100 = \Sigma_{t=1}^{10}(1/(1 + \rho))^{t}20$.

Although this is an extremely widespread approach for measuring discount rates, it relies on a variety of additional (and usually implicit) assumptions, and is subject to several confounding factors.

6.1.1 *Consumption Reallocation*

The calculation outlined above assumes a sort of "isolation" in decision making. Specifically, it treats the objects of intertemporal choice as discrete, unitary, dated events; it assumes that people entirely "consume" the reward (or penalty) at the moment it is received, as if it were an instantaneous burst of utility. Furthermore, it assumes that people don't shift consumption around over time in anticipation of the receipt of the future reward or penalty. These assumptions are rarely exactly correct, and may sometimes be bad approximations. Choosing between \$50 today versus \$100 next year, or choosing between 50 pounds of corn today versus 100 pounds next year, are not the same as choosing between 50 utils today and 100 utils on the same day next year, as the calculations imply. Rather, they are more complex choices between the various streams of consumption that those two dated rewards make possible.

6.1.2 *Intertemporal Arbitrage*

In theory, choices between tradable rewards, such as money, should not reveal anything about time preferences. As Victor Fuchs (1982) and others have noted, if capital markets operate effectively (if monetary amounts at different times can be costlessly exchanged at a specified interest rate), choices between dated monetary outcomes can be reduced to merely selecting the reward with the greatest net present value (using the market interest rate).[28] To

[28] Meyer (1976) expresses this point: ". . . if we can lend and borrow at the same rate . . . , then we can simply show that, regardless of the fundamental orderings on the *c*'s [consumption streams], the induced ordering on the *x*'s [sequences of monetary flows] is given by simple discounting at this given rate. . . . We could say that the market assumes command and the market rate prevails for monetary flows."

illustrate, suppose a person prefers $100 now to $200 ten years from now. While this preference *could* be explained by imputing a discount rate on future utility, the person might be choosing the smaller immediate amount because she believes that through proper investment she can turn it into more than $200 in ten years, and thus enjoy more than $200 worth of consumption *at that future time*. The presence of capital markets should cause imputed discount rates to converge on the market interest rate.

Studies that impute discount rates from choices among tradable rewards assume that respondents ignore opportunities for intertemporal arbitrage, either because they are unaware of capital markets or unable to exploit them.[29] The latter assumption may sometimes be correct. For instance, in field studies of electrical-appliance purchases, some subjects may have faced borrowing constraints that prevented them from purchasing the more expensive energy-efficient appliances. More typically, however, imperfect capital markets cannot explain choices; they cannot explain why a person who holds several thousand dollars in a bank account earning 4-percent interest should prefer $100 today over $150 in one year. Because imputed discount rates do not, in fact, converge on the prevailing market interest rates, but instead are much higher, it seems that many respondents are neglecting capital markets and basing their choices on some other consideration, such as time preference or the uncertainty associated with delay.

[29] Arguments about violations of the discounted utility model assume, as Pender (1996, pp. 282–83) notes, "that the results of discount rate experiments reveal something about intertemporal preferences directly. However, if agents are optimizing an intertemporal utility function, their opportunities for intertemporal arbitrage are also important in determining how they respond to such experiments . . . when tradable rewards are offered, one must either abandon the assumption that respondents in experimental studies are optimizing, or make some assumptions (either implicit or explicit) about the nature of credit markets. The implicit assumption in some of the previous studies of discount rates appears to be that there are no possibilities for intertemporal arbitrage. . . ."

6.1.3 *Concave Utility*

The standard approach to estimating discount rates assumes that the utility function is linear in the magnitude of the choice objects (e.g., amounts of money, pounds of corn, duration of some health state). If, instead, the utility function for the good in question is concave, estimates of time preference will be biased upward. For example, indifference between $100 this year and $200 next year implies a *dollar* discount rate of 100 percent. However, if the utility of acquiring $200 is less than twice the utility of acquiring $100, the *utility* discount rate will be less than 100 percent. This confound is rarely discussed, perhaps because utility is assumed to be approximately linear over the small amounts of money commonly used in time-preference studies. The overwhelming evidence for reference-dependent utility suggests, however, that this assumption may be invalid—that people may not be integrating the stated amounts with their current and future wealth, and therefore that curvature in the utility function may be substantial even for these small amounts (see Ian Bateman et al. 1997; David W. Harless and Colin F. Camerer 1994; Kahneman and Tversky 1979; Rabin 2000; Rabin and Thaler 2001; Tversky and Kahneman 1991).

Three techniques could be used to avoid this confound. (1) One could request direct utility judgments (e.g., attractiveness ratings) of the same consequence at two different times. Then, the ratio of the attractiveness rating of the distant outcome to the proximate outcome would directly reveal the implicit discount factor. (2) To the extent that utility is linear in probability, one can use choices or judgment tasks involving different probabilities of the same consequence at different times (Alvin E. Roth and J. Keith Murnighan 1982). Evidence that probability is weighted nonlinearly (see, e.g., Starmer 2000) would, of course, cast doubt on this approach. (3) One can separately elicit the utility function for the good in question, and then use that function to transform outcome amounts into utility amounts, from which utility discount rates could be computed. To our knowledge, Chapman (1996) conducted the only study that attempted to do this. She found that *utility* discount rates were substantially lower than the *dollar* discount rates, because utility was strongly concave over the monetary amounts subjects used in the intertemporal choice tasks.[30]

6.1.4 *Uncertainty*

In experimental studies, subjects are typically instructed to assume that delayed rewards will be delivered with certainty. It is unclear whether subjects do (or can) accept this assumption, because delay is ordinarily—and perhaps unavoidably—associated with uncertainty. A similar problem arises for field studies, in which it is typically assumed that subjects believe that future rewards, such as energy savings, will materialize. Because of this subjective (or "epistemic") uncertainty associated with delay, it is difficult to determine to what extent the magnitude of imputed discount rates (or the shape of the discount function) is governed by time preference *per se*, versus the diminution in subjective probability associated with delay.[31]

Empirical evidence suggests that introducing objective (or "aleatory") uncertainty to both current and future rewards can dramatically affect estimated discount rates. For instance, Gideon Keren and Peter Roelofsma (1995) asked one group of respondents to choose between 100 florins (a Netherlands unit of currency) immediately and 110 florins in one month, and another group to choose between a 50-percent chance of 100 florins immediately and a 50-percent chance of 110 florins in one month. While 82 percent preferred the smaller immediate reward when both rewards were certain, only 39 percent preferred the smaller immediate reward when both rewards were uncertain.[32] Also, Albrecht and Weber (1996) found that the present value of a future lottery (e.g., a 50-percent chance of receiving 250 deutsche marks) tended to exceed the present value of its certainty equivalent.

6.1.5 *Inflation*

The standard approach assumes that, for instance, $100 now and $100 in five years generate the same level of utility at the times they are received. However,

[30] Chapman also found that magnitude effects were much smaller after correcting for utility function curvature. This result supports Loewenstein and Prelec's (1992) explanation of magnitude effects as resulting from utility function curvature (see section 5.2.2).

[31] There may be complicated interactions between risk and delay, because uncertainty about future receipt complicates and impedes the planning of one's future consumption stream (Michael Spence and Richard Zeckhauser 1972). For example, a 90-percent chance to win $10,000,000 in fifteen years is worth much less than a guarantee to receive $9,000,000 at that time, because, to the extent that the person cannot insure against the residual uncertainty, there is a limit to how much she can adjust her consumption level during those fifteen years.

[32] This result cannot be explained by a magnitude effect on the expected amounts, because 50 percent of a reward has a *smaller* expected value, and, according to the magnitude effect, should be discounted more, not less.

inflation provides a reason to devalue future monetary outcomes, because in the presence of inflation, $100 worth of consumption now is more valuable than $100 worth of consumption in five years. This confound creates an upward bias in estimates of the discount rate, and this bias will be more or less pronounced depending on subjects' experiences with and expectations about inflation.

6.1.6 *Expectations of Changing Utility*

A reward of $100 now might also generate more utility than the same amount five years hence because a person expects to have a larger baseline consumption level in five years (e.g., due to increased wealth). As a result, the marginal utility generated by an additional $100 of consumption in five years may be less than the marginal utility generated by an additional $100 of consumption now. Like inflation, this confound creates an upward bias in estimates of the discount rate.

6.1.7 *Habit Formation, Anticipatory Utility, and Visceral Influences*

To the extent that the discount rate is meant to reflect *only* time preference, and not the confluence of *all* factors influencing intertemporal choice, the modifications to the instantaneous utility function discussed in section 5 represent additional biasing factors, because they are typically not accounted for when the discount rate is imputed. For instance, if anticipatory utility motivates one to delay consumption more than one otherwise would, the imputed discount rate will be lower than the true degree of time preference. If a person prefers an increasing consumption profile due to habit formation, the discount rate will be biased downward. Finally, if the prospect of an immediate reward momentarily stimulates visceral factors that temporarily increase the person's valuation of the proximate reward, the discount rate could be biased upward.[33]

6.1.8 *An Illustrative Example*

To illustrate the difficulty of separating time preference *per se* from these potential confounds, consider a prototypical study by Benzion, Rapoport, and Yagil (1989). In this study, respondents equated immediate sums of money and larger delayed sums (e.g., they specified the reward in six months that would be as good as getting $1000 immediately). In the cover story for the questionnaire, respondents were asked to imagine that they had earned money (amounts ranged from $40 to $5000), but when they arrived to receive the payment they were told that the "financially solid" public institute is "temporarily short of funds." They were asked to specify a future amount of money (delays ranged from six months to four years) that would make them indifferent to the amount they had been promised to receive immediately. Surely, the description "financially solid" could scarcely be sufficient to allay uncertainties that the future reward would actually be received (particularly given that the institute was "temporarily" short of funds), and it seems likely that responses included a substantial "risk premium." Moreover, the subjects in this study had "extensive experience with . . . a three-digit inflation rate,"

[33] It is unclear whether visceral factors should be considered a determinant of time preference or a confounding factor in its estimation. If visceral factors increase the attractiveness of an immediate reward without affecting its experienced enjoyment (if they increase wanting but not liking), they are probably best viewed as a legitimate determinant of time perference. If, however, visceral factors alter the amount of utility that a contemplated proximate reward actually delivers, they might best be regarded as a confounding factor.

and respondents might well have considered inflation when generating their responses. Even if respondents assumed no inflation, the real interest rate during this time was positive, and they might have considered intertemporal arbitrage. Finally, respondents may have considered that their future wealth would be greater and that the later reward would therefore yield less marginal utility. Indeed, the instructions cued respondents to consider this, as they were told that the questions did not have correct answers, and that the answers "might vary from one individual to another depending on his or her present or future financial assets."

Given all of these confounding factors, is it unclear exactly how much of the imputed annual discount rates (which ranged from 9 percent to 60 percent) actually reflected time preference. It is possible that the responses in this study (and others) can be entirely explained in terms of these confounds, and that once these confounds are controlled for, no "pure" time preference would remain.

6.2 *Procedures for Measuring Discount Rates*

We discussed above several confounding factors that greatly complicate the assignment of a discount rate to a particular choice or judgment. With these confounds in mind, we next discuss the methods that have been used to measure discount rates. Broadly, these methods can be divided into two categories: *field studies*, in which discount rates are inferred from economic decisions that people make in their ordinary life, and *experimental studies*, in which people are asked to evaluate stylized intertemporal prospects involving real or hypothetical outcomes. The different procedures are each subject to the confounds discussed above, and, as we shall discuss, are also influenced by a variety of other factors that are theoretically irrelevant, but which can greatly affect the imputed discount rate.

6.2.1 *Field Studies*

Some researchers have estimated discount rates by identifying real-world behaviors that involve tradeoffs between the near future and more distant future. Early studies of this type examined consumers' choices among different models of electrical appliances, which presented purchasers with a tradeoff between the immediate purchase price and the long-term costs of running the appliance (as determined by its energy efficiency). In these studies, the discount rates implied by consumers' choices vastly exceeded market interest rates and differed substantially across product categories. The implicit discount rate was 17–20 percent for air conditioners (Jerry Hausman 1979); 102 percent for gas water heaters, 138 percent for freezers, 243 percent for electric water heaters (H. Ruderman, M. D. Levine, and J. E. McMahon 1987); and from 45 percent to 300 percent for refrigerators, depending on assumptions made about the cost of electricity (Dermot Gately 1980).[34]

[34] These findings illustrate how people seem to ignore intertemporal arbitrage. As Hausman (1979) noted, it does not make sense for anyone with positive savings to discount future energy savings at rates higher than the market interest rate. One possible explanation for these results is that people are liquidity constrained. Consistent with such an account, Hausman found that the discount rate varied markedly with income—it was 39 percent for households with under $10,000 of income, but just 8.9 percent for households earning between $25,000 and $35,000. However, conflicting with this finding, a study by Douglas Houston (1983) that presented individuals with a decision of whether to purchase a hypothetical "energy-saving" device, found that income "played no statistically significant role in explaining the level of discount rate."

Another set of studies imputes discount rates from wage-risk tradeoffs, in which individuals decide whether to accept a riskier job with a higher salary. Such decisions involve a tradeoff between quality of life and expected length of life. The more that future utility is discounted, the less important is length of life, making risky but high-paying jobs more attractive. From such tradeoffs, W. Kip Viscusi and Michael Moore (1989) concluded that workers' implicit discount rate with respect to future life years was approximately 11 percent. Later, using different econometric approaches with the same data set, Moore and Viscusi (1990a) estimated the discount rates to be around 2 percent, and Moore and Viscusi (1990b) concluded that the discount rate was somewhere between 1 percent and 14 percent. Mark Dreyfus and Viscusi (1995) applied a similar approach to auto-safety decisions and estimated discount rates ranging from 11 percent to 17 percent.

In the macroeconomics literature, researchers have imputed discount rates by estimating structural models of life-cycle saving behavior. For instance, Emily Lawrence (1991) used Euler equations to estimate household time preferences across different socioeconomic groups. She estimated the discount rate of median-income households to be between 4 percent and 13 percent depending on the specification. Christopher Carroll (1997) criticizes Euler-equation estimation on the grounds that most households tend to engage mainly in "buffer-stock" saving early in their lives—they save primarily to be prepared for emergencies—and only conduct "retirement" saving later on. Recent papers have estimated rich, calibrated, stochastic models in which households conduct buffer-stock saving early in life and retirement saving later in life. Using this approach, Carroll and Andrew Samwick (1997) report point estimates for the discount rate ranging from 5 percent to 14 percent, and Pierre-Olivier Gourinchas and Jonathan Parker (2001) report point estimates of 4.0–4.5 percent. Field studies of this type have the advantage of not assuming isolation, because integrated decision making is built into the model. But such estimates often depend heavily on the myriad assumptions included in the structural model.[35]

Recently, John Warner and Saul Pleeter (2001) analyzed decisions made by U.S. military servicemen. As part of military downsizing, over 60,000 military employees were given the choice between a one-time, lump-sum payment and an annuity payment. The sizes of the payments depended on the employee's current salary and number of years of service—e.g., an "E-5" with nine years of service could choose between $22,283 now vs. $3,714 every year for eighteen years. In general, the present value of the annuity payment equaled the lump-sum payment for a discount rate of 17.5 percent. Although the interest rate was only 7 percent at the time of these decisions, over half of all military officers and over 90 percent of enlisted personnel chose the lump-sum payment.[36] This study is particularly compelling in terms of credibility of reward delivery, magnitude of stakes, and number of subjects.[37]

[35] These macroeconomics studies are not included in the tables and figures, which focus primarily on individual level choice data.

[36] It should be noted, however, that the guaranteed payments in the annuity program were not indexed for inflation, which averaged 4.2 percent during the four years preceding this choice.

[37] Warner and Pleeter (2001) noted that if everyone had chosen the annuity payment, the present value of all payments would have been $4.2 billion. Given the choices, however, the present value of the government payout was just 2.5 billion. Thus, offering the lump-sum alternative saved the federal government $1.7 billion dollars.

The benefit of field studies, as compared with experimental studies, is their high *ecological* validity. There is no concern about whether estimated discount rates would apply to real behavior because they are estimated from such behavior. But field studies are subject to additional confounds due to the complexity of real-world decisions and the inability to control for some important factors. For example, the high discount rates implied by the widespread use of inefficient electrical appliances might not result from the discounting of future cost savings per se, but from other considerations, including: (1) a lack of information among consumers about the cost savings of the more efficient appliances; (2) a disbelief among consumers that the cost savings will be as great as promised; (3) a lack of expertise in translating available information into economically efficient decisions; or (4) hidden costs of the more efficient appliances, such as reduced convenience or reliability, or, in the case of light bulbs, because the more efficient bulbs generate a less aesthetically pleasing light spectra.[38]

6.2.2 *Experimental Studies*

Given the difficulties of interpreting field data, the most common methodology for eliciting discount rates is to solicit "paper-and-pencil" responses to the prospect of real and hypothetical rewards and penalties. Four experimental procedures are commonly used: choice tasks, matching tasks, pricing tasks, and ratings tasks.

Choice tasks are the most common experimental method for eliciting discount rates. In a typical choice task, subjects are asked to choose between a smaller, more immediate reward and a larger, more delayed reward. Of course, a single choice between two intertemporal options only reveals an upper or lower bound on the discount rate—for example, if a person prefers 100 units of something today over 120 units a year from today, the choice merely implies a discount rate of *at least* 20 percent per year. To identify the discount rate more precisely, researchers often present subjects with a series of choices that vary the delay or the amount of the rewards. Some studies use real rewards, including money, rice, and corn. Other studies use hypothetical rewards, including monetary gains and losses, and more or less satisfying jobs available at different times. (See table 1 for a list of the procedures and rewards used in the different studies.)

Like all experimental elicitation procedures, the results from choice tasks can be affected by procedural nuances. A prevalent problem is an anchoring effect: when respondents are asked to make multiple choices between immediate and delayed rewards, the first choice they face often influences subsequent choices. For instance, people would be more prone to choose $120 next year over $100 immediately if they first chose between $100 immediately and $103 next year than if they first chose between $100 immediately and $140 next year. In general, imputed discount rates tend to be biased in the direction of the discount rate that would equate the first pair of options to which they are exposed (see Donald Green et al. 1998). Anchoring effects can be minimized by using titration procedures that expose respondents to a series of opposing anchors—e.g., (1) $100 today or $101 in one year? (2) $100 today or $10,000 in one year? (3) $100 today or $105 in one year? and so on. Because titration procedures typically only offer

[38] For a criticism of the hidden-costs explanation, however, see Jonathan Koomey and Alan Sanstad (1994) and Richard Howarth and Sanstad (1995).

choices between an immediate reward and a *greater* future reward, however, even these procedures communicate to respondents that they should be discounting, and potentially bias discount rates upward.

Matching tasks are another popular method for eliciting discount rates. In matching tasks, respondents "fill in the blank" to equate two intertemporal options (e.g., $100 now = _____ in one year). Matching tasks have been conducted with real and hypothetical monetary outcomes and with hypothetical aversive health conditions (again see table 1 for a list of the procedures and rewards used in different studies). Matching tasks have two advantages over choice tasks. First, because subjects reveal an indifference point, an exact discount rate can be imputed from a single response. Second, because the intertemporal options are not fully specified, there is no anchoring problem and no suggestion of an expected discount rate (or range of discount rates). Thus, unlike choice tasks, matching tasks cannot be accused of simply recovering the expectations of the experimenters that guided the experimental design.

Although matching tasks have some advantages over choice tasks, there are reasons to be suspicious of the responses obtained. First, responses often appear to be governed by the application of some simple rule rather than by time preference. For example, when people are asked to state the amount in *n* years that equals $100 today, a very common response is $100*$n$. Second, the responses are often very "coarse"—often multiples of two or ten of the immediate reward, suggesting that respondents do not (or cannot) think very carefully about the task. Third, and most importantly, there are large differences in imputed discount rates among several theoretically equivalent procedures. Two intertemporal options could be equated or matched in one of four ways: Respondents could be asked to specify (1) the amount of a delayed reward that would make it as attractive as a given immediate reward (which is the most common technique); (2) the amount of an immediate reward that makes it as attractive as a given delayed reward (Albrecht and Weber 1996); (3) the maximum length of time they would be willing to wait to receive a larger reward in lieu of an immediately available smaller reward (Ainslie and Haendel 1983; Roelofsma 1994); or (4) the latest date at which they would accept a smaller reward in lieu of receiving a larger reward at a specified date that is later still.

While there is no theoretical basis for preferring one of these methods over any other, the small amount of empirical evidence comparing different methods suggests that they yield very different discount rates. Roelofsma (1994) found that implicit discount rates varied tremendously depending on whether respondents matched on amount or time. One group of subjects was asked to indicate how much compensation they would demand to allow a purchased bicycle to be delivered nine months late. The median response was 250 florins. Another group was asked how long they would be willing to delay delivery of the bicycle in exchange for 250 florins. The mean response was only three weeks, implying a discount rate that is twelve times higher. Frederick and Read (2002) found that implicit discount rates were dramatically higher when respondents generated the future reward that would equal a specified current reward than when they generated a current reward that would equal a specified future reward. Specifically, when respondents were asked to state the amount in thirty years that would be as good as getting

$100 today, the median response was $10,000 (implying that a future dollar is 1/100th as valuable), but when asked to specify the amount today that is as good as getting $100 in thirty years, the median response was $50 (implying that a future dollar is 1/2 as valuable).

Two other experimental procedures involve rating or pricing temporal prospects. In *rating tasks*, each respondent evaluates an outcome occurring at a particular time by rating its attractiveness or aversiveness. In *pricing tasks*, each respondent specifies a willingness to pay to obtain (or avoid) some real or hypothetical outcome occurring at a particular time, such as a monetary reward, dinner coupons, an electric shock, or an extra year added to the end of one's life. (Once again, see table 1 for a list of the procedures and rewards used in the different studies.) Rating and pricing tasks differ from choice and matching tasks in one important respect. Whereas choice and matching tasks call attention to time (because each respondent evaluates two outcomes occurring at two different times), rating and pricing tasks permit time to be manipulated *between subjects* (because a single respondent may evaluate either the immediate or delayed outcome, by itself).

Loewenstein (1988) found that the timing of an outcome is much less important (discount rates are much lower) when respondents evaluate a single outcome at a particular time than when they compare two outcomes occurring at different times, or specify the value of delaying or accelerating an outcome. In one study, for example, two groups of students were asked how much they would pay for a $100 gift certificate at the restaurant of their choice. One group was told that the gift certificate was valid immediately. The other was told it could be used beginning six months from now. There was no significant difference in the valuation of the two certificates *between* the two groups, which implies negligible discounting. However, when asked how much they would pay [have to be paid] to use it six months earlier [later], the timing became important—the delay group was willing to pay $10 to expedite receipt of the delayed certificate, while the immediate group demanded $23 to delay the receipt of a certificate they expected to be able to use immediately.[39]

Another important design choice in experimental studies is whether to use real or hypothetical rewards. The use of real rewards is generally desirable for obvious reasons, but hypothetical rewards actually have some advantages in this domain. In studies involving hypothetical rewards, respondents can be presented with a wide range of reward amounts, including losses and large gains, both of which are generally infeasible in studies involving real outcomes. The disadvantage of hypothetical choice data is the uncertainty about whether people are motivated to, or capable of, accurately predicting what they would do if outcomes were real.

To our knowledge, only two studies have compared discounting between real and hypothetical rewards. Kirby and Marakovic (1995) asked subjects to state the immediate amount that would make them indifferent to some fixed delayed amount (delayed reward sizes were $14.75, $17.25, $21.00, $24.50, $28.50; delays were 3, 7, 13, 17, 23, and 29 days). One group of subjects answered all thirty permutations for real rewards, and another group of subjects

[39] Rating tasks (and probably pricing tasks as well) are subject to anchoring effects. Shelley and Thomas Omer (1996), Mary Kay Stevenson (1992), and others have found that a given delay (e.g., six months) produces greater time discounting when it is considered alongside shorter delays (e.g., one month) than when it is considered alongside longer delays (e.g., three years).

answered all thirty permutations for hypothetical rewards. Discount rates were *lower* for hypothetical rewards.[40] Maribeth Coller and Melonie Williams (1999) asked subjects to choose between \$500 payable in one month and \$500 + \$*x* payable in three months, where \$*x* was varied from \$1.67 to \$90.94 across fifteen different choices. In one condition, all choices were hypothetical; in five other conditions, one person was randomly chosen to receive her preferred outcome for one of her fifteen choices. The raw data suggest again that discount rates were considerably lower in the hypothetical condition, although they suggest that this conclusion is not supported after controlling for censored data, demographic differences, and heteroskedasticity (across demographic differences and across treatments).[41] Thus, there is, as of yet, no clear evidence that hypothetical rewards are discounted differently than real rewards.[42]

6.3 *Conclusion: What Is Time Preference?*

Figure 2 reveals spectacular disagreement among dozens of studies that all purport to be measuring time preference. This lack of agreement likely reflects the fact that the various elicitation procedures used to measure time preference consistently fail to isolate time preference, and instead reflect, to varying degrees, a blend of both pure time preference and other theoretically distinct considerations, including: (a) intertemporal arbitrage, when tradeable rewards are used; (b) concave utility; (c) uncertainty that the future reward or penalty will actually obtain; (d) inflation, when nominal monetary amounts are used; (e) expectations of changing utility; and (f) considerations of habit formation, anticipatory utility, and visceral influences.

Figure 2 also reveals a predominance of high implicit discount rates—discount rates well above market interest rates. This consistent finding may also be due to the presence of the various extra-time-preference considerations listed above, because nearly all of these work to bias imputed discount rates upward—only habit formation and anticipatory utility bias estimates downward. If these confounding factors were adequately controlled, we suspect that many intertemporal choices or judgments would imply much lower—indeed, possibly even zero—rates of time preference.

Our discussion in this section highlights the conceptual and semantic ambiguity about what the concept of "time preference" ought to include—about what properly counts as time preference per se and what ought to be called something else (for further discussion,

[40] The two results were not strictly comparable, however, because they used a different procedure for the real rewards than for the hypothetical rewards. An auction procedure was used for the real-rewards group only. Subjects were told that whoever, of three subjects, stated the lowest immediate amount would receive the immediate amount, and the other two subjects would receive the delayed amount. Optimal behavior in such a situation involves overbidding. Since this creates a downward bias in discount rates for the real-rewards group, however, it does not explain away the finding that real discount rates were higher than hypothetical discount rates.

[41] It is hard to understand which control eliminates the differences that are apparent in the raw data. It would seem not to be the demographic differences per se, because the hypothetical condition had a "substantially higher proportion of non-white participants" (p. 121) and "non-whites on average reveal discount rates that are nearly 21 percentage points higher than those revealed by whites" (p. 122).

[42] There has been considerable recent debate outside of the context of intertemporal choice about whether hypothetical choices are representative of decisions with real consequences. The general conclusion from this debate is that the two methods typically yield qualitatively similar results (see Camerer and Robin Hogarth 1999 for a recent review), though systematic differences have been observed in some studies (Ronald Cummings, Glenn Harrison, and Elisabet Rutstrom 1995; Yoram Kroll, Haim Levy, and Rapoport 1988).

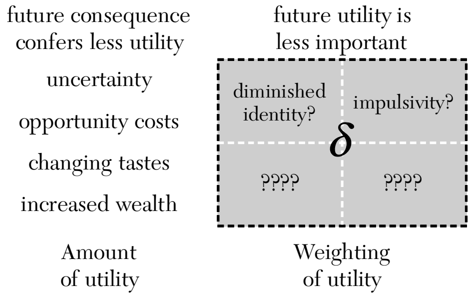

Figure 3.

see Frederick 1999). We have argued here that many of the reasons for caring when something occurs (e.g., uncertainty or utility of anticipation) are not time preference, because they pertain to the expected amount of utility consequences confer, and not to the weight given to the utility of different moments (see figure 3, adapted from Frederick 1999). However, it is not obvious where to draw the line between factors that operate through utilities and factors that make up time preference.

Hopefully, economists will eventually achieve a consensus about what is included in, and excluded from, the concept of time preference. Until then, drawing attention to the ambiguity of the concept will hopefully improve the quality of discourse by increasing awareness that, in discussions about time preference, different people may be using the same term to refer to significantly different underlying constructs.[43]

7. *Unpacking Time Preference*

As detailed in section 2, early twentieth-century economists' conceptions of intertemporal choice included detailed accounts of disparate underlying psychological motives. With the advent of the DU model in 1937, however, economists eschewed considerations of specific motives, proceeding as if all intertemporal behavior could be explained by the unitary construct of time preference. In sections 5 and 6, we highlighted several factors that influence intertemporal decisions, but which would not be considered time preference as the term is ordinarily used. In this section, we turn our focus inward and question whether even time preference itself should be regarded as a unitary construct.

Issues of this type are hotly debated in psychology. For example, psychologists debate the usefulness of conceptualizing intelligence in terms of a single unitary "g" factor. Typically, a posited psychological construct (or "trait") is considered useful only if it satisfies three criteria: (1) it remains relatively constant across time within a particular individual; (2) it predicts behavior across a wide range of situations, and (3) different measures of it correlate highly with one another. The concept of intelligence satisfies these criteria fairly well.[44] First, performance in tests of

[43] Not only do people use the same term to refer to different concepts (or sets of concepts), they also use different terms to represent the same concept. The welter of terms used in discussions of intertemporal choice include: discount factor, discount rate, marginal private rate of discount, social discount rate, utility discount rate, marginal social rate of discount, pure discounting, time preference, subjective rate of time preference, pure time preference, marginal rate of time preference, social rate of time preference, overall time preference, impatience, time bias, temporal orientation, consumption rate of interest, time positivity inclination, and "the pure futurity effect." John Broome (1995, pp. 128–29) notes that some of the controversy about discounting results from differences in how the term is used: "On the face of it . . . typical economists and typical philosophers seem to disagree. But actually I think there is more misunderstanding here than disagreement . . . When economists and philosophers think of discounting, they typically think of discounting different things. Economists typically discount the sorts of goods that are bought and sold in markets [whereas] philosophers are typically thinking of a more fundamental good, people's *well-being* . . . It is perfectly consistent to discount commodities and not well-being."

[44] Debates remain, however, about whether traditional measures exclude important dimensions, and whether a multidimensional account of

cognitive ability at early ages correlates highly with performance on such tests at all subsequent ages. Second, cognitive ability (as measured by such tests) predicts a wide range of important life outcomes, such as criminal behavior and income. Third, abilities that we regard as expressions of intelligence correlate strongly with each other. Indeed, when discussing the construction of intelligence tests, Herrnstein and Charles Murray (1994, p. 3) note that, "It turned out to be nearly impossible to devise items that plausibly measured some cognitive skill [which] were *not* positively correlated with other items that plausibly measured some cognitive skill."

The posited construct of time preference does not fare as well by these criteria. First, no longitudinal studies have been conducted to permit any conclusions about the temporal stability of time preference.[45] Second, correlations between various measures of time preference or between measures of time preference and plausible real-world expressions of it are modest, at best. Chapman and Elstein (1995) and Chapman, Richard Nelson, and Daniel Hier (1999) found only weak correlations between discount rates for money and for health, and Chapman and Elstein (1995) found almost no correlation between discount rates for losses and for gains. Fuchs (1982) found no correlation between a prototypical measure of time preference (e.g., "Would you choose $1500 now or $4000 in five years?") and other behaviors that would plausibly be affected by time preference (e.g., smoking, credit-card debt, seat-belt use, and the frequency of exercise and dental checkups). Nor did he find much correlation among any of these reported behaviors (see also Nyhus 1995).[46] Chapman and Elliot Coups (1999) found that corporate employees who chose to receive an influenza vaccination did have significantly lower discount rates (as inferred from a matching task with monetary losses), but found no relation between vaccination behavior and hypothetical questions involving health outcomes. Lalith Munasinghe and Sicherman (2000) found that smokers tend to invest less in human capital (they have flatter wage profiles), and many others have found that for stylized intertemporal choices among monetary rewards, heroin addicts have higher discount rates (e.g., Leanne Alvos, R. A. Gregson, and Michael Ross 1993; Kirby, Petry, and Bickel 1999; Gregory Madden et al. 1997; Thomas Murphy and Alan De Wolfe 1986; Petry, Bickel, and Martha Arnett 1998).

Although the evidence in favor of a single construct of time preference is hardly compelling, the low cross-behavior correlations do not necessarily

intelligence would have even greater explanatory power. Robert Sternberg (1985), for example, argues that intelligence is usefully decomposed into three dimensions: (1) analytical intelligence, which includes the ability to identify problems, compute strategies, and monitor solutions, and is measured well by existing IQ tests; (2) creative intelligence, which reflects the ability to generate problem-solving options, and (3) practical intelligence, which involves the ability to implement problem-solving options.

[45] Although there have been no longitudinal studies of time preference per se, Mischel and his colleagues did find that a child's capacity to delay gratification was significantly correlated with *other* variables assessed decades later, including academic achievement and self esteem (Ozlem Ayduk et al. 2000; Mischel, Yuichi Shoda, and Peake 1988; Shoda, Mischel, and Peake 1990). Of course, this provides evidence for construct validity only to the extent that one views these other variables as expressions of time preference. We also note that while there is little evidence that intertemporal behaviors are stable over long periods, there is some evidence that time preference is not strictly constant over time for all people. Heroin addicts discount both drugs and money more steeply when they are craving heroin than when they are not (Louis Giordano et al. 2001).

[46] A similar lack of *intraindividual* consistency has been observed in risk-taking (Kenneth MacCrimmon and Donald Wehrung 1990).

disprove the existence of time preference. Suppose, for example, that someone expresses low discount rates on a conventional elicitation task, yet indicates that she rarely exercises. While it is possible that this inconsistency reflects true heterogeneity in the degree to which she discounts different types of utility, perhaps she rarely exercises *because* she is so busy at work earning money for her future or because she simply cares much more about her future finances than her future cardiovascular condition. Or, perhaps she doesn't believe that exercise improves health. As this example suggests, many factors could work to erode cross-behavior correlations, and thus, such low correlations do not mean that there can be no single unitary time preference, underlying all intertemporal choices (the intertemporal analog to hypothesized construct of "g" in analyses of cognitive performance). However, notwithstanding this disclaimer, in our view the cumulative evidence raises serious doubts about whether there is, in fact, such a construct—a stable factor that operates identically on, and applies equally to, all sources of utility.[47]

To better understand the pattern of correlations in implied discount rates across different types of intertemporal behaviors, we may need to unpack time preference itself into more fundamental motives, as illustrated by the segmentation of the delta component of figure 3. Loewenstein et al. (2001) have proposed three specific constituent motives, which they labeled *impulsivity* (the degree to which an individual acts in a spontaneous, unplanned fashion), *compulsivity* (the tendency to make plans and stick with them), and *inhibition* (the ability to inhibit the automatic or "knee-jerk" response to the appetites and emotions that trigger impulsive behavior).[48] Preliminary evidence suggests that these subdimensions of time preference can be measured reliably. Moreover, the different subdimensions predict different behaviors in a highly sensible way. For example, repetitive behaviors such as flossing one's teeth, exercising, paying one's bills on time, and arriving on time at meetings were all predicted best by the compulsivity subdimension. Viscerally driven behaviors, such as reacting aggressively to someone in a car who honks at you at a red light, were best predicted by impulsivity (positively) and behavioral inhibition (negatively). Money-related behaviors such as saving money, having unpaid credit-card balances, or being maxed out on one or more credit cards were best predicted by conventional measures of discount rates (but impulsivity and compulsivity were also highly significant predictors).

Clearly, further research is needed to evaluate whether time preference is best viewed as a unitary construct or a composite of more basic constituent motives. Further efforts hopefully will be informed by recent discoveries of neuroscientists, who have identified regions of the brain whose damage leads to extreme myopia (Antonio R. Damasio 1994) and areas that seem to play an important role in suppressing the behavioral expression of urges (Joseph E.

[47] Note that one can also *over*estimate the strength of the relationship between measured time preference and time-related behaviors or between different time-related behaviors if these variables are related to characteristics such as intelligence, social class, or social conformity, that are not adequately measured and controlled for.

[48] Recent research by Roy Baumeister, Todd Heatherton, and Diane Tice (1994) suggests that such "behavioral inhibition" requires an expenditure of mental effort that, like other forms of effort, draws on limited resources—a "pool" of willpower (Loewenstein 2000a). Their research shows that behavioral inhibition in one domain (e.g., refraining from eating desirable food) reduces the ability to exert willpower in another domain (e.g., completing a taxing mental or physical task).

LeDoux 1996). If some behaviors are best predicted by impulsivity, some by compulsivity, some by behavioral inhibition, and so on, it may be worth the effort to measure preferences at this level and to develop models that treat these components separately. Of course, such multidimensional perspectives will inevitably be more difficult to operationalize than formulations like the DU model, which represent time preference as a unidimensional construct.

8. *Conclusions*

The DU model, which continues to be widely used by economists, has little empirical support. Even its developers—Samuelson, who originally proposed the model, and Koopmans, who provided the first axiomatic derivation—had concerns about its descriptive realism, and it was never empirically validated as the appropriate model for intertemporal choice. Indeed, virtually every core and ancillary assumption of the DU model has been called into question by empirical evidence collected in the past two decades. The insights from this empirical research have spawned new theories of intertemporal choice that revive many of the psychological considerations discussed by early students of intertemporal choice—considerations that were effectively dismissed with the introduction of the DU model. Additionally, some of the most recent theories show that intertemporal behaviors may be dramatically influenced by people's level of understanding of how their preferences change—by their "metaknowledge" about their preferences (see, e.g., O'Donoghue and Rabin 1999b; Loewenstein, O'Donoghue, and Rabin 2000).

While the DU model assumes that intertemporal preferences can be characterized by a single discount rate, the large empirical literature devoted to measuring discount rates has failed to establish any stable estimate. There is extraordinary variation across studies, and sometimes even within studies. This failure is partly due to variations in the degree to which the studies take account of factors that confound the computation of discount rates (e.g., uncertainty about the delivery of future outcomes or nonlinearity in the utility function). But the spectacular cross-study differences in discount rates also reflect the diversity of considerations that are relevant in intertemporal choices and that legitimately affect different types of intertemporal choices differently. Thus, there is no reason to expect that discount rates *should* be consistent across different choices.

The idea that intertemporal choices reflect an interplay of disparate and often competing psychological motives was commonplace in the writings of early twentieth-century economists. We believe that this approach should be resurrected. Reintroducing the multiple-motives approach to intertemporal choice will help us to better understand and better explain the intertemporal choices we observe in the real world. For instance, it permits more scope for understanding individual differences (e.g., why one person is a spendthrift while his neighbor is a miser, or why one person does drugs while her brother does not), because people may differ in the degree to which they experience anticipatory utility or are influenced by visceral factors.

The multiple-motive approach may be even more important for understanding *intra*-individual differences. When one looks at the behavior of a single individual across different domains, there is often a wide range of apparent attitudes toward the future. Someone may smoke heavily, but carefully study the returns of various retirement packages. Another may squirrel money away while, at the same time, giving little thought to electrical efficiency when purchasing an air conditioner. Someone else may devote two decades of his life to establishing a career, and then jeopardize this long-term investment for some highly transient pleasure. Since the DU model assumes a unitary discount rate that applies to all acts of consumption, such intra-individual heterogeneities pose a theoretical challenge. The multiple-motive approach, by contrast, allows us to readily interpret such differences in terms of more narrow, more legitimate, and more stable constructs—e.g., the degree to which people are skeptical of promises, experience anticipatory utility, are influenced by visceral factors, or are able to correctly predict their future utility.

The multiple-motive approach may sound excessively open-ended. We have described a variety of considerations that researchers could potentially incorporate into their analyses. Including every consideration would be far too complicated, while picking and choosing which considerations to incorporate may leave one open to charges of being ad hoc. How, then, should economists proceed?

We believe that economists should proceed as they typically do. Economics has always been both an art and a science. Economists are forced to intuit, to the best of their abilities, which considerations are likely to be important in a particular domain and which are likely to be largely irrelevant. When economists model labor supply, for instance, they typically do so with a utility function that incorporates consumption and leisure, but when they model investment decisions, they typically assume that preferences are defined over wealth. Similarly, a researcher investigating charitable giving might use a utility function that incorporates altruism but not risk aversion or time preference, whereas someone studying investor behavior is unlikely to use a utility function that incorporates altruism. For each domain, economists choose the utility function that is best able to incorporate the essential considerations for that domain, and then evaluate whether the inclusion of specific considerations improves the predictive or explanatory power of a model. The same approach can be applied to multiple-motive models of intertemporal choice. For drug addiction, for example, habit formation, visceral factors, and hyperbolic discounting seem likely to play a prominent role. For extended experiences, such as health states, careers, and long vacations, the preference for improvement is likely to come into play. For brief, vivid experiences, such as weddings or criminal sanctions, utility from anticipation may be an important determinant of behavior.

In sum, we believe that economists' understanding of intertemporal choices will progress most rapidly by continuing to import insights from psychology, by relinquishing the assumption that the key to understanding intertemporal choices is finding the right discount rate (or even the right discount function), and by readopting the view that intertemporal choices reflect many distinct considerations and often involve the interplay of several competing motives. Since different motives may be evoked to different degrees by different situations (and by different descriptions of the *same* situation), developing descriptively adequate models of intertemporal choice will not be easy. But we hope this paper will help.

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