Economic Perspectives on Addiction: Hyperbolic Discounting and Internalities

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Abstract:
This paper provides an introduction, with critical interpretations, to the use of hyperbolic discounting as a model of behavior for the consumption of addictive goods. The exponential and hyperbolic discounting models are carefully reviewed, with particular emphasis on the implications for time consistency. We then present a simple explanation of the logic of market failure resulting from internalities and the economic inefficiency that can result when time inconsistent choices have inter-temporal impacts. We then briefly review, with commentary, key work, from the experimental and broader empirical literature, that can be used to assess and critique the hyperbolic discounting model.

Key words: internalities, hyperbolic discounting, addiction, welfare analysis

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Why do people become addicted? The standard economic model of the consumer views addiction as resulting from a choice maximizing the consumer's perceived utility or welfare. In other words, a person becomes addicted because it's in his or her best interest to become addicted – the benefits from consuming the addictive good (possibly including prestige among peers, etc.) outweigh the costs (including addiction and health consequences). Although this model of "rational addiction" (Becker and Murphy, 1988) has had much influence and even wide acceptance within the field of economics, the view of addiction as rational behavior has not enjoyed a similar reception in the field of public health. In the view of these public health researchers, the choice to become addicted is not a rational choice, it is a *mistaken* choice.

In this paper we provide an introduction to some key issues in this debate, and a structure for how these issues can be interpreted from the perspective of economics. We focus on a fundamental, if not *the* fundamental, alternative to the model of rational addiction that is being discussed by behavioral economists and psychologists. This is a modification of the rational addiction model that allows for the possibility that consumers are hyperbolic discounters. The exact meaning of these terms is provided below, but the essence of the distinction is that, although similar to the classic rational consumer, a hyperbolic discounting consumer will not behave consistently over time and will thus be unable to sustain optimal consumption paths, *i.e.*, dynamically optimize, in the consumption of addictive goods. Our additional objective is to clarify and discuss how economists and public health researchers can interpret this behavioral model of hyperbolic discounting to measure the social welfare costs of the consumption of addictive goods. This involves the market failure logic of "internalities," or externalities that consumers impose on their future selves, implicit in an assumption of hyperbolic discounting with addiction.

We set the groundwork for this discussion with a brief review of the standard rational choice models for addictive goods consumption, and arguments that have been made for how we can have market failures even within these rational-choice frameworks. We then carefully explain the logic of hyperbolic discounting, discuss how it can lead to preference reversals in the consumption of addictive goods that are inconsistent with dynamic welfare maximization, and explain how one can measure the resulting welfare losses. Finally, we review some of the critiques of the hyperbolic discounting model and discuss some of the cautions that should be taken in the interpretation of its social welfare implications, and conclude.

1. Standard models of addictives consumption:

As was carefully discussed by Becker and Murphy (1988) in their original paper, an important factor for determining an individual's behavior in the standard economic or "rational" model of the consumer is the patience level of that individual. The consumption of addictive goods usually involves some present benefit, such as validation by one's peers, pleasure, or relief from withdrawal symptoms. This consumption can, however, bring with it potentially high future costs, such as adverse health outcomes and early death. We thus normally expect a patient person, one that is willing to make present sacrifices for future rewards, to be less likely to consume a harmful addictive good. All else equal we would also thus expect someone who cares less about her future well being, to be more likely to become addicted.

The consumption of addictive goods resulting from this impatience does not, in itself, represent a mistake or market failure. From the perspective of the present-focused teenager who doesn't care much about future consequences, such addiction can be perfectly rational and welfare maximizing. We only see a market failure if we posit that the present-focused teenager, who took up the addiction, should not have been sovereign.

As discussed by Laux (2000), this is the form of market failure that was featured in the economic rational for the U.S. Food and Drug Administration's 1996 initiative to curb youth smoking. The FDA argument was that, since it is and was illegal for underage kids to purchase cigarettes in all 50 US states, one can stipulate that teenage consumers are not sovereign when it comes to smoking decisions and that the welfare effects of smoking decisions should be defined and measured by reference to adult preferences, and not youth preferences.[1]

The rational addiction model of Becker and Murphy was extended by Orphanides and Zevros (1995) to take into account the possibility of regret, *i.e.*, that the impact of an addictive substance on any particular individual is likely to be

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[1] Stigler and Becker (1977) had an important influence on the profession by arguing that economic models should treat consumer preferences as fixed. They argued that to attribute changes in behaviors to changes in the fundamentals of tastes doesn't tell us anything. For example, concluding that Consumer X makes different choices than Consumer Y, because Consumer X *likes* to make different choices than Consumer Y is not much of a conclusion. Stigler and Becker suggest an alternative approach to explaining differences in "tastes" across consumers in terms of household production functions – different households have different assets and abilities, which cause them to have different capacities for converting goods into utility. As Stigler and Becker suggested but did not emphasize, their logic can and has been extended to dynamic contexts of apparent changes in tastes across time. Thus, a health-conscious adult may appear to be more future-oriented or patient than he was as a cigarette-smoking teenager only because his adult self has a different household production function. The problem with this argument is that it is difficult to conceive how such a household production could reconcile typical consumer behavior with harmful addictives. Time invariant preferences for the typical addict would require that a forward-looking teenager, who is investing in the capital stock for his own future household production, will simultaneously destroy his capacity to make use of this investment. It also requires that the teenage production planner puts less weight on perhaps 50 years of expected future utility than the adult planner will put on perhaps 20 years of expected future utility.

uncertain. Some individuals are less prone to addiction and can successfully quit addictive habits.[2] Others may find it difficult or impossible to quit using an addictive substance, even though they experience little enjoyment from their continued use and observe obvious deteriorations in their health. Any given individual, however, is not likely to know which type of person he or she is prior to experimentation. The uncertainty of this gamble and resulting population of addicts, who may have started their consumption of addictives with plans to quit, is one explanation for the existence of the "unhappy addicts," debated in the literature. Although the existence of unhappy addicts may convince some that a decision to take up an addictive behavior cannot be rational, Orphanides and Zevros demonstrate that an unwanted addiction can quite conceivably result from rational choice and does not, in itself, imply a mistake in decision making. This is because the choice to experiment could have been a gamble that was *ex ante* rational, which appears, *ex post* to have been a mistake. Even when betting on even odds, not all gamblers will win.

Loewenstein, O'Donoghue and Rabin (2003) develop an extended form of this regret model that does deal with systematic, *ex ante* errors in consumer decision making. Like Orphanides and Zevros, these authors' consumer also faces uncertainty about the future; the difference is that Loewenstein et al. specify that their consumer will suffer from projection bias. In the consumption of addictive goods, this projection bias amounts to a systematic underestimation of the extent of their future addiction. As documented in the Loewenstein et al paper, there is substantial empirical support for the existence of this kind of projection bias. Such projection bias will lead to suboptimal decisions and, in that sense, market failures.

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[2] The Epidemiology and Statistics Unit of the American Lung Association (2003) uses National Health Interview Survey data to estimate that 49.2% of living U.S. adults who had ever smoked more than 100 cigarettes had quit smoking by the year 2001.

A third possibility for market failure that is consistent with the standard rational choice model, comes from the possibility that some individuals may be truly unaware or misinformed about the addictive potential and health consequences of consuming an addictive good. Unlike the above models of learning to regret, these consumers may seriously underestimate the addictive potential of a good not just for themselves, but in general, as it affects the entire population. For the case of cigarettes, influential work has been done on this question by Viscusi (1992), who finds that U. S. teenagers systematically *overestimate* the risks of smoking, instead of underestimating these risks; but there is widespread evidence that other populations (Chinese males for example) systematically underestimate smoking risks. Slovic (2000) and Arnett (2000), among others, contest Viscusi's conclusions by noting that adolescents (and adult smokers) systematically underestimate the risks of smoking for themselves personally, as compared to their reported beliefs about risks to other smokers. Slovic also reports that, although some teenagers (not all) may overestimate the long-term risks of smoking, they tend to underestimate the short-term risks that, given their expectations that they will soon quit smoking, they find more relevant.

In this paper we discuss an alternative explanation for the decision to consume harmful addictives, the possibility of hyperbolic discounting. The resulting model departs from the rational choice framework and has its roots in behavioral economics and psychology. It observes that, when decisions involve plans of action to be followed over time, there is the possibility that consumers will fail to implement these plans, or will act inconsistently. Before entering into this discussion, however, we first present a brief review of standard rational-choice model of intertemporal decision making under exponential discounting, which provides the foundation for the hyperbolic discounting model.

2. Exponential Discounting:

The canonical model of inter-temporal choice, developed principally by Irving Fisher (1930) and Paul Samuelson (1937), can be stated as follows. An individual chooses a consumption path (c_0, c_1,…,c_T) to maximize lifetime utility:

(1) $$\sum_{t=0}^{T} \delta^t u(c_t)$$

subject to

(2) $$\sum_{t=0}^{T} c_t /(1+r)^t = W \; .$$

Where c_t is consumption in period *t*, *r* is the market rate of interest and *W*, referred to as wealth, is the net present value of the consumer's future income plus present wealth, evaluated at time 0. The instantaneous utility function, *u*, is assumed to be stationary, and thus has no time subscript. The constraint states that the discounted value of the consumption stream (c_0, c_1,…,c_T) has to equal the discounted value of the consumer's purchasing power. This particular form of the budget constraint assumes perfect capital markets; the individual can lend and borrow at the market rate of interest *r*.

Parameter δ is the individual's discount factor. The standard assumption is that $0 < \delta < 1$, that is, future utility is counted in current decisions but is given less weight than current utility.[3] In other words, individuals typically exhibit some impatience to advance the timing of consumption but are not completely myopic. Total myopia corresponds to δ equal to zero; in this case the future consequences of today's choices

[3] Although it is commonly assumed that $0 < \delta < 1$, consumers can and do sometimes behave as if their discount factors, δ, are greater than 1. In financial markets, this would be analogous to negative real interest rates.

are not taken into account. Some of the first models of addiction developed by economists assumed total myopia and are now referred to, naturally enough, as the myopic theories of addiction.

The type of personal discounting employed in equation (1), exponential discounting, is a very special case that has some very desirable properties. First of all, it is completely characterized by one parameter, δ. Exponential discounting is thus easy to work with, requiring only minimal notation. A more profound consequence, however, is that an exponential discounter is "time consistent" (Strotz, 1956).[4] Time consistency means that, if the consumer chooses a plan at time zero then, as time progresses, the consumer will stick to that plan. As long as a consumer's preferences are stable over time, a consumer or addict who discounts exponentially will not put off actions that are unpleasant, *e.g.*, her quit-smoking date, once that action has been scheduled as part of her consumption plan.

3. <u>Hyperbolic Discounting:</u>

Do individuals discount exponentially? The following thought experiment suggests otherwise. Consider the option of receiving $500 immediately or $520 next week. Perhaps not all but certainly many individuals will opt to receive the slightly smaller amount of $500 immediately. Now consider presenting a similar option of receiving $500 in 100 weeks or $520 in 101 weeks. Clearly we expect that most of those who would have originally opted not to wait one week for a $20 increment in near-term payments will opt to wait an extra week to receive $20 extra in payments to

[4] We note that in his 1956 paper, Strotz implicitly argues that non-exponential discounting was fairly common. He also realized that the non-exponential discounting would give rise to "self control" problems over time. Strotz argues that a number of real world institutions can be understood as mechanism to address problems of self control (he gives "Christmas Clubs" as an example).

be received 101 weeks from now. Consumers who reveal such preferences are not exponential discounters.[5]

To see this, assume that such a consumer were an exponential discounter with a weekly discount rate of δ. The fact that she prefers $500 now to $520 next week means

$$u(500) > \delta u(520)$$

while preferring $520 in 101 weeks over $500 in 100 weeks, means that, for her,

$$\delta^{101}u(520) > \delta^{100}u(500)$$

implying a contradiction.

There are several ways to model non-exponential discounting. The method we focus on, widely used in the psychology and behavioral economics literatures, is so-called hyperbolic discounting (see, for example, Laibson, 1997).[6] Here the discount scheme applied to present and future utilities takes the form:

(3) $$1,\ \beta\delta,\ \beta\delta^2,\ \beta\delta^3,\ \beta\delta^4,\ldots..$$

Thus the consumption path ($c_0, c_1,\ldots,c_T$) has a discounted value given by:

(4) $$u(c_0) + \sum_{t=1}^{T} \beta\delta^t u(c_t)\,,$$

where it is typically assumed that β is positive but less than 1.[7]

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[5] This anomaly is also called the common difference effect and is discussed by Lowenstein and Prelec (1992). An extensive review of the literature on time preferences, which includes some discussion of hyperbolic discounting, is provided by Frederick et al. (2002).

[6] Though there are earlier papers dating back to the late 1960's, recent interest in hyperbolic discounting and its connection with self-control problems is due to the work of Laibson (1997). Laibson has focused on the problems of saving – do people save enough for retirement, for example.

[7] Numerous other forms for hyperbolic discounting have been used. Perhaps the most general, in terms of the shapes it can support for the weighting of future payoffs, is that of Loewenstein and Prelec (1992), where $U(c_1, c_2, \ldots, c_T) = \sum_{1}^{T} \left[1/(1+gt)\right]^{h/g} u(c_t)$.

This specification is attractive for a number of reasons. First, it is fully characterized by only two parameters, β and δ, making it relatively easy to work with. Second, for $\beta = 1$, we have exponential discounting so that exponential discounting is a special case of hyperbolic discounting. Accordingly, one can talk about slight departures from exponential discounting by setting β slightly less than 1 and examining behavior as β approaches 1. If one is willing to assume that consumers "should" discount exponentially, this framework also facilitates policy analysis. Optimal policies are calculated by setting $\beta = 1$ and the analyst can then ask what kind of incentives are needed to guide behavior when $\beta < 1$ (see, for example, Gruber and Koszegi, 2004).[8] Finally, this hyperbolic representation captures many of the stylized facts that are usually put forth as indications of departures from exponential discounting. For example, the behavior described in the above thought experiment can be accommodated in a hyperbolic discounting model by allowing β to be less than 1.

What is the connection between time inconsistency and hyperbolic discounting? A heuristic way to see what is going on is to realize that the discounting scheme (3) is non-stationary in the following sense.[9] At time 0, the hyperbolic individual applies the following sequence $1,\ \beta\delta,\ \beta\delta^2,\ \beta\delta^3,\ \beta\delta^4, \ldots$ of discount rates to present and future utility. Hence period 0's utility is weighted 1 while period 1's utility is weighted βδ, and period 2 utility is weighted by $\beta\delta^2$. One period later, the same sequence of discount rates is again applied to present and future utilities. At this

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The $\sum_{t=1}^{T} \beta\delta^t u(c_t)$ form we use is sometimes referred to as "quasi-hyperbolic" discounting and is the form most commonly used in the economics literature.

[8] Since only exponential discounting can be time consistent and since welfare maximization across time in a stochastic environment requires time consistency, there is no clear alternative to this assumption that β "should" equal one.

[9] Koopmans (1960) is a classic axiomatic derivation of exponential discounting that establishes the tight link between stationarity and exponential discounting.

point in time, however, the weighting factors will have shifted so that there is no discounting for period 1 consumption, a factor of $\beta\delta$ is applied for period 2 consumption, and so forth. The relative weights applied to period 1 versus period 2 have shifted from δ to $\beta\delta$. This shift in relative discount weights for adjacent periods implies that the optimal program viewed from the period 1 perspective will be different from the optimal program determined from the vantage of period 0.

To make sure this point is clear, consider the following four-period example. The second row gives the discount rates applied at period 0 to the current period and all the subsequent periods. The third row lists the discount rates used in period 1, and so forth.

Period	0	1	2	3
0	1	$\beta\delta$	$\beta\delta^2$	$\beta\delta^3$
1		1	$\beta\delta$	$\beta\delta^2$
2			1	$\beta\delta$
3				1

In period 0, the ratio of the discount rates for period 3 and 2 is $\beta\delta^3/\beta\delta^2 = \delta$; this ratio is the same when viewed from period 1. In period 2, however, period 2 utility is weighted by 1 while period 3 utility is discounted by $\beta\delta$. Hence the ratio of between-period discount rates will change over time. This means that, in period 2, the individual will want revise plans so as to increase period 2 consumption and decrease period 3 consumption. Accordingly, the individual will not be able to sustain an optimal consumption path (time inconsistency arises).

4. Hyperbolic Discounting and Addiction:

What does this have to do with addiction and addictive behavior?[10] One key aspect of addiction is that quitting is costly. Given, perhaps because of a shock to consumer preferences due to peer group pressure or a personal crisis, that present rewards from the consumption of an addictive are high enough, an informed rational consumer may choose to take up an addictive habit and thus to become addicted. If the addiction is harmful, future payoffs will then be lower for such an addicted consumer. To return to higher long-run payoffs, associated with non-addiction, this consumer has to incur cessation costs that are often high. Hyperbolic discounting, because of the altered marginal rate of substitution between present versus future consumption that follows a consumer's choice path, can induce procrastination for a consumer who confronts these cessation costs.

The following bare-bones model of addiction illustrates this choice problem faced by a hyperbolic discounting consumer in the consumption of addictive goods.[11] At time zero, the individual faces two alternatives, *A* and *B*, that yield the following sequence of payoffs:

$$A = \{N, N, N, N, \ldots\}$$

$$B = \{E, A, A, A, \ldots\}$$

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[10] O'Donoghue and Rabin (1999b) apply hyperbolic discounting to this kind of modeling of addiction. Pursuing the much different objective of generalizing the Becker and Murphy (1988) model of rational addiction, Gruber and Koszegi (2001) discuss the application of such a model of hyperbolic discounting to the empirical estimation of consumer behavior in cigarette consumption.

[11] This model is similar in spirit to O'Donoghue and Rabin (1999b), but even simpler. Following the lead of O'Donoghue and Rabin (1999b), much of the simplification in our presentation is generated by assuming that choices are discrete – one either becomes addicted or does not and, if addicted, one either quits or does not. Becker and Murphy (1988), on the other hand, assume that consumption decisions are continuous – thus the option of using a vanishingly small amount of the addictive good is available (though it may not be optimal).

A is the non-addiction path and *B* is the addictive path. If $E > N$, that is, use of the addictive substance gives a higher short run payoff (*E* for ecstasy) than the non-addiction option (*N* for non-addiction), then the consumer may choose addiction. If the addiction is harmful, then $A < N$.

After becoming addicted, the individual faces another set of choices at each time period, a choice between B' and *C*.

$$B' = \{A, A, A\ldots\}$$

$$C = \{W, N, N, \ldots\}.$$

For an addictive good $W < A$, implying that there is a cost, $W - A$, of withdrawal (*W*).

How does the issue of time consistency tie in with this structure? Given the choices *A*, *B*, B' and *C*, an individual may plan to consume the addictive for some time (choice *B*) and then quit (choice *C*). If the individual, who decides upon this consumption path, is an exponential discounter then she would be expected to execute this plan in full (or else she wouldn't have made it). If the individual is a hyperbolic discounter, however, then such a plan may go unimplemented.

The decision to use the addictive substance can be modeled as follows.[12] To simplify the analysis suppose that the individual lives forever.[13] The benefits from addiction will be higher than the benefits from abstention if

$$(5) \qquad E + \beta(\delta A + \delta^2 A + \delta^3 A + \ldots) > N + \beta(\delta N + \delta^2 N + \delta^3 N + \ldots).$$

Using the fact that $1 + \delta + \delta^2 + \ldots$ equals $1/(1-\delta)$ and rearranging, (5) is equivalent to

$$(6) \qquad E - N > \frac{\beta\delta}{1-\delta}\left(N - A\right),$$

[12] Clearly, the decision to become addicted may be motivated by other shocks, such as changes in peer group or life crises, not considered in our simple modeling.
[13] Or that the probability of survival from period to period is constant.

that is, addiction occurs when (6) holds.

When is (6) likely to be true? Examining this expression, we see that addiction is likely to occur if *N* is small and *E* is large. It is also more likely to occur if β is small, that is, significantly less than one so that the departure from exponential discounting is large. Can an exponential discounter become addicted? If β is 1 and the individual's δ is close to 1, then the right-hand side of expression (6) is large, and addiction is less likely to occur. If the individual's δ is close to 0, however, then even if β is 1, the right-hand side of expression (6) will still be small and addiction will be more likely.

Inequality (6) also indicates that addiction is less likely to occur if *N* is large and *A* is small, implying a high cost of being addicted. This reflects that the main insights of the rational addiction approach are retained in this model. A final point worth noting is that even in this very stripped down model, the discount parameters β and δ, which economists think of as representing idiosyncratic variation in tastes and personality, have an important influence over the decision to become addicted. Thus it is possible that perfectly informed individuals, who are aware of the true values of *E*, *N* and *A*, may still, because of their β and δ values, choose to become addicted. The policy implication is that truthful counter-advertising and the provision of the information about addictive substances, even if the information is properly understood and interpreted, may not persuade all people to avoid harmful addictives.

Moving beyond the start decision, once an individual is addicted, our simple analysis assumes that she will decide to quit whenever her benefits from quitting outweigh her costs. In the simple model considered here, she will choose to use the addictive substance in period 0, but then quit the next period whenever the above condition (5) plus the following condition holds:

(7) $$E + \beta(W\delta + N\delta^2 + N\delta^3 + \dots) > E + \beta(A\delta + A\delta^2 + A\delta^3 + \dots)$$

This above condition (7) says that the benefits of quitting more then compensate for the cost of withdrawal. Condition (5) ensures that addiction, the right-hand side of conditions (7) is more attractive than abstinence. Accordingly, this individual decides to consume the addictive while planning to endure the cost of quitting, *W*, immediately after her short period of "experimentation." Simplifying the above expression (7), this individual plans on quitting after one period because

(8) $$A - W < \frac{\delta}{1-\delta}(N - A)$$

Note that β does not enter into this individual's calculation of her future plans. Thus, although our form of hyperbolic discounting influences consumption initiation decisions, it has no impact on future plans to quit. This individual will thus plan to quit, but not execute that plan whenever

(9) $$\frac{\delta}{1-\delta}(N - A) > A - W > \frac{\beta\delta}{1-\delta}(N - A)$$

This simple model has a bearing on the following observation. Many young smokers claim that they will stop smoking at an early age; 16 year-old smokers often claim that they will stop in their early twenties. The percentage of smokers who actually quit in their twenties is, however, much lower than the percentage of 16 year-olds who announce such plans. One way to explain this disconnect is that some of these 16 year-olds are hyperbolic discounters – they may know all relevant payoffs, but have β values that are sufficiently low so that they become perpetual procrastinators. This interpretation is also consistent with the rather large percentage of older smokers who state that they want to quit but find it too difficult to do so.

This interpretation also has policy implications. It suggests that incomplete information is not necessary to explain regret in addiction. Unwanted long-term addictions can also arise via various combinations of discount parameters δ and β. Of course, it easy to see, within this framework, that misinformation can also give rise to addiction. If an individual underestimates withdrawal costs, that is, thinks that the utility they will derive in their withdrawal period is $W' > W$, then the individual is more likely to become addicted. Additionally one can consider whether or not the consumer knows she is a hyperbolic discounter. An unsophisticated hyperbolic discounter, who does not take into account her own lack of time consistency and propensity to procrastinate, will be more likely to become addicted. A sophisticated hyperbolic discounter, who is aware of her propensity to procrastinate, may, however, be reluctant to experiment with addictive substances.[14] The hyperbolic discounter may, however, only learn of her problem through experience, which may explain why younger decision makers seem more prone to adopt time-inconsistent consumption plans.

5. <u>Internalities:</u>

A well-known cause of market failure is the presence of an externality. An externality is said to exist when decision makers, in the process of choosing actions, inadvertently affect the well being (positively or negatively) of others, in ways that are not reflected in prices. Classic examples of negative externalities are traffic congestion and pollution. Education and basic scientific research are often cited as generating positive externalities.

"Internalities," a term that seems to have been invented by Herrnstein et al. (1993), arise when an individual makes decisions in the present that will affect the well being of her future self. For example, if an individual is consuming a good for

[14] Even sophisticated consumers will, however, fall victim to these self-control problems.

which future desire to consume is influenced by past consumption history, then present consumption choices will impose an internality. A simple way of expressing such an internality mathematically is to make the current instantaneous utility of the consumer conditional on her consumption history (restricted, below, to just previous-period consumption).

$$u(y_0, x_0) + \beta \sum_{t=1}^{T} \delta^t u(y_t, x_t \mid x_{t-1}) \qquad (10)$$

Here, the level of good x consumed at time zero, x_0, has an impact on period 1 utility; x_1 has an impact on period 2 utility, and so forth. Clearly, the existence of an internality does not, in itself, imply market failure (nor does the existence of an externality). This is because x_0 may be chosen in a way that takes into account any impact it has on future incarnations so as to maximize the discounted lifetime utility of the consumer. It is easy to see the parallel between externalities and internalities. With an externality, a person chooses an action that impacts someone else. With an internality, this action impacts her own future self, as if this future self were someone else. An internality is, of course, only of interest when choices made in the present, when considered in the context of their lifetime impact, are inefficient.

With the inter-temporal utility structure of (10) there are two circumstances that could result in an inefficient choice of x_0. First, the individual might at time 0 undervalue the utility that accrues to her future selves. This will be the case if β is less than one, that is, if the individual is a hyperbolic discounter. Second, if the individual is poorly informed about the future consequences of current actions. For example, she may misperceive the interconnection between present actions and future utility levels. The measurement of any welfare loss associated with hyperbolic discounting or misperceptions then depends on a comparison of the consumer's realized consumption history, with internality, to projections of what it would have been without the internality or information failure.[15]

There is another parallel between externalities and internalities. An externality induced market failure may justify government intervention. With internalities, government intervention may offer similar improvements to market outcomes by helping individuals better manage choice across time. Laibson (1996) has argued tax and subsidy measures may be needed to ensure that individuals make adequate provisions for accumulating savings over the course of their lifetime. More on point to our topic of addiction, Gruber and Koszegi (2004) have made similar suggestions that the lifetime utility of many hyperbolic discounting smokers may be raised by higher taxes.

The challenge for the measurement of the social cost of internalities lies in deciding how to weight the importance of the welfare of a given consumer across time. Could the preferences or "utility" of a teenager be more important than those of an adult? Other than for the above-mentioned reasons of analytical convenience and tractability, why should we assume that exponentially declining weights describe the social welfare ideal? Perhaps some periods during our lives, such as infancy and the courtship period before a wedding are more important and deserve more weight.

[15] In the case of hyperbolic discounting, these projections will be based on the addictiveness of the good (defining the internality-effect influence of past and present consumption on future consumption); an estimate of demand elasticity (to estimate projected consumption levels at adjusted prices, where these adjusted prices will include the addiction and health burden of any internality); hyperbolic discounting parameter β and a definition of the ideal inter-temporal discount function for the consumer (which combined with the above information, allows estimates of the corrective compensating variation for the consumer). Existing analyses, see Gruber and Koszegi (2004), have assumed that the correct measurement of consumer welfare uses exponential discounting and is derived from the existing hyperbolic discounting function after changing β to equal 1.

Indeed, Paul Samuelson was aware of this concern when he first articulated his model of exponential discounting. He concluded his 1937 article with the paragraph:

> *"In conclusion, any connection between utility as discussed here and any welfare concept is disavowed. The idea that results of such a statistical investigation could have any influence upon ethical judgments of policy is one which deserves the impatience of modern economists."*
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> -- Samuelson (1937, p. 161)[16]

To the extent that policy decisions require that an assumption be made, we suggest that reference be made to the U.S. Office of Management and Budget Circular A-4 (2003). This suggests that exponential discounting be assumed to describe the proper weighting of an individual's inter-temporal welfare and that discount rates of 3% and 7%, approximately equal to those defined by financial markets, be assumed.

6. Critique of hyperbolic discounting:

The critique of hyperbolic discounting can be considered as coming from two different levels. The most frequent, in our view, and perhaps fundamental criticism is driven not by disagreement with the science involved in estimating or interpreting hyperbolic discounting behavior, but by concern about the paternalistic policy implications that may be drawn by such analyses. The second, more technical line of criticism questions whether the model is supported by the evidence. We restrict our discussion to this second, more technical line of criticism, which is directly focused on the evidence.

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[16] We found this Samuelson quote after seeing a shorter excerpt reproduced in Frederick et al. (2002).

Rather than review this literature in its entirety, we restrict ourselves to some highlights (for more extensive reviews of this literature see Frederick et al., 2002, and Van der Pol and Cairns, 2002). Tests of hyperbolic discounting, conducted both in laboratory experiments and using field data, tend to compare the hyperbolic model with exponential discounting and tend very much to support the former. Regardless of this, however, both the model and these tests remain controversial. In our view, the most important challenge to the validity of the hyperbolic discounting model comes from the recognition that the immediacy bias, *i.e.*, hyperbolic discounting, that experimental test subjects exhibit may simply reflect their lack of confidence in promises of future rewards. In other words, whereas they may view an immediate payoff as a sure payoff, they may see a promised future payoff as an uncertain payoff. Such doubts will clearly confound any laboratory test of hyperbolic versus exponential discounting and, if not carefully controlled for, can mislead analysts in their support of the hyperbolic model.

Keren and Roelofsema (1995, p. 289) illustrate this point by referring to an example of Richard Herrnstein's (1990). This is that, if asked to choose between $100 tomorrow and $115 a week from tomorrow, most will choose the $100 payment. If, however, asked to choose between $100 in 52 weeks versus $115 in 53 weeks, most will choose the $115 payment. Keren and Roelofsema (KR) argue that this result may have less to do with hyperbolic discounting and more to do with uncertainty and perhaps instinctive doubts over the credibility of promises. To explore this, they conduct various experiments. The first replicates the above story by asking 60 Dutch subjects to choose between receiving 100 Florins instantly and 110 Florins in 4 weeks. The smaller, immediate payment is preferred by 82% of these subjects. They then integrate uncertainty into this analysis, presumably to introduce doubt over the receipt of immediate payments as well as delayed payments, by asking a pool of 100 subjects to choose between a 50% chance of getting 100 Florins instantly (versus nothing) and a 50% chance of getting 110 Florins in 4 weeks (versus nothing). Under these conditions of uncertainty, 61% of test subjects preferred to wait for the chance at 110 Florins. When similar uncertainty was injected into choices between 100 versus 110 Florins one year from now, versus one year and 4 weeks from now, no significant variation in selection patterns was observed.

An independent and also influential line of criticism by Daniel Read (see Read 2003) leads to different conclusions that are perhaps related to these KR results. Read's hypothesis of subadditivity says that investigators who believe they are observing hyperbolic discounting, which psychologists model as a gradual reduction in discount rate over time, may actually be seeing a human tendency to use more moderate discount rates in estimating lost value over long time intervals while we use more extreme discounting for shorter time intervals. In other words, the combined discounting that we would apply to many short intervals will yield greater total discounting than what we would apply to a single time-equivalent long interval. Read suggests that the correct model is thus one of subadditivity in time preference, not hyperbolic discounting.

As noted by Read (1993, footnote 12), an alternative interpretation of his results is that individuals engage in a distinct form of discounting only for the first time interval (the lapse between now and next week, for example). Thus, although they discount heavily in a short time interval that spans from the present to the near future, they discount moderately in any short time period spanning two future dates. Although this is inconsistent with the $U(c_1, c_2, \ldots, c_T) = \sum_1^T [1/(1+gt)]^{h/g} u(c_t)$, formula for hyperbolic discounting commonly used by psychologists, it is not inconsistent with the simpler $U(c_1, c_2, \ldots, c_T) = \sum_{t=1}^{T} \beta\delta^t u(c_t)$ formula, or "(β,δ) formulation," typically used by economists and featured in this present paper.[17] Interestingly, this subadditivity result that is consistent with the economists' modeling convention could also result from the immediacy and uncertainty effects discussed above of KR.

Seemingly in favor of hyperbolic discounting, some clean and convincing field data evidence of heavy (if not hyperbolic) discounting by consumers is provided by Warner and Pleeter (2001). They report on results on a military downsizing program that offered 65,000 uniformed service members the choice between a lump sum and an annuity payment, in return for their voluntary separation from the armed services. Although the breakeven discount rate between these choices varied from 17.5% to 19.8% (depending on years of service), 51% of the 11,212 officers given the offer selected the lump sum and 92% of the 55,271 enlisted persons accepted. Since the typical lump sum payment for officers was around $50,000 and for enlisted personnel was around $25,000, these were high-stakes decisions. Accounting for tax impacts and expected interest rates, the real break-even rates implied by these choice options ranged from about 16 to 23% (Warner and Pleeter, 2001, p. 43).[18] Warner and Pleeter use these data to estimate the implied mean personal discount rates for all officers and enlisted personnel who were eligible for these separations (only about 23% of those eligible actually elected early separation and thus actually faced the

[17] Evidence in favor of this (β,δ) formula, used by economists, is also provided by a cross-study or meta-analysis review of how discount factors vary across time, displayed in Figures 1a and 1b of Frederick et al. (2002, p. 362).

[18] A complication in the Warner and Pleeter analysis is that, for a portion of their sample (those separating from service in FY92) a choice of the lump sum payment allowed access to other benefits. Using dummy variables to measure the impact of any such bias for that sub-sample, however, showed that these additional benefits induced an upward bias of no more than 1% in discount rate estimates for the affected officers and less than that for affected enlisted service members.

lump-sum versus annuity decision). Comparing results from linear and log-linear probit estimates, respectively, they predict a range of between 10.4 and 18.7% for officers and 35.4 and 53.6% for enlisted persons.

It is difficult to imagine how the enormous disparity between these numbers, especially for enlisted persons, and market rates of interest can be explained within the convention, exponential-discounting model. Clearly, liquidity constraints could be a factor, but it is hard to imagine this being such a big factor. Presumably, the promise of a government annuity would have allowed many of these departing service persons to obtain loans. The fact that the military provided extensive publicity informing eligible individuals of the financial logic of this choice (including illustrations that, assuming a 7% interest rate, the annuity choice was far superior), makes this even harder to understand. Clearly, the immediacy effect emphasized by Keren and Roelofsema may have had some role in this outcome. Although a clean test of hyperbolic discounting was not available from these data, the result is certainly consistent with hyperbolic discounting and illustrates a large welfare loss for the subject sample.

Further evidence in support of hyperbolic discounting is found by Angeletos et al. (2001) who use simulation models to compare assumptions of exponential versus hyperbolic discounting (β,δ formulation) to the actual savings behavior of U.S. households. The simulations are calibrated to match empirical data, from the Survey of Consumer Finance and the Panel Study of Income Dynamics,[19] on labor income and income shocks, discount rates, and other factors. Hyperbolic discounters are assumed to have a β of .7 and discount factors, δ, are further calibrated to the data. The key assumption is that those households that follow hyperbolic discounting are

[19] They calibrate the simulations to match the sub-samples of these surveys consisting of respondents who graduated from high school but did not complete college.

assumed to be sophisticated, or self-aware, with regard to their self-control problem. Households can choose between saving money in liquid, versus illiquid investments (and have some access to credit card debt). By skewing their savings toward illiquid investments, e.g., home ownership, hyperbolic discounters can reduce the negative impact of their self control problems.

Although the share of savings held in liquid versus illiquid assets was much higher for both types of simulated households than it is in the data, households with hyperbolic discounting had lower levels of liquid asset holdings and were closer to the data on this dimension.[20] The use of credit card debt by hyperbolic discounters (51% of households, versus 19% for exponential discounters) much more closely approximated what one observes in the data. Reflecting the difficulty that consumers have in achieving consumption smoothing, simulating households with hyperbolic discounting had an average marginal propensity to consume out of predictable changes in income of 16.6%, well above the 3% number for simulated exponential discounters and close to the 19% to 33% that these authors estimated in the data. Angeletos et al. thus found that simulations that assumed hyperbolic discounting by consumers seem to fit much better with the data than simulations based on an exponential discounting assumption.

In sum, our reaction to the criticism of the model of hyperbolic discounting as not being supported by the empirical evidence is that we see this as being more of a concern in the experimental literature, and specifically relating to the concerns of Keren and Roelofsema regarding the need to separate immediacy from uncertainty effects. As for the existence of a market failure in market data, although some

[20] Angeletos et al. reasonably argue that this lack of fit may be attributable to differences in definition. Real estate and other illiquid asset holdings in the data are often more convertible or liquid than illiquid assets were assumed to be in their modeling. They assumed a $10,000 fixed fee for selling an illiquid asset plus a 10% penalty against asset value.

individuals seem to handle intertemporal consumption decisions reasonably well, it's hard to see how enlisted persons in the armed forces could sustain personal discount rates of between 35.4 and 53.6% for extended periods of time. Such individuals would make essentially no investment in the future, which flies in the face of the ability of these persons to maintain steady employment, etc. Thus, the most likely explanation for such results would be stable discounting that is, at times, hyperbolic or time inconsistent. By explicitly comparing hyperbolic discounting with exponential discounting as an explanation for some persistent riddles in the life-cycle consumption literature, the work of Angeletos et al. lends further support to the hypothesis of hyperbolic discounting.

Another point we wish to emphasize, which seems largely overlooked in the existing literature, is that market failures attributable to time-inconsistent consumer behavior can lead to important welfare losses even if only some portion of the population is affected. Thus, the emphasis on mean effects, which we see in the literature, seems very much misplaced. This can be most clearly seen in the contexts of cigarette, alcohol, and illicit drug consumption. If only a small percentage of the population has trouble controlling these addictions, the resulting welfare loss can be enormous. Thus, although existing studies seem to indicate that either excessive discounting or hyperbolic discounting affects a large portion of the population; these models still have force even if they are applicable only to small population minorities.

7. Conclusions:

This paper provides an introductory and critical review of hyperbolic discounting. We show the logic of how a momentary lapse or crisis, together with the tendency toward procrastination implied by this form of discounting, can lead to the long-term consumption of addictives. We further explain, through the logic of internalities, how much of this long-term consumption of addictives can be interpreted as resulting from market failure.

For future research and thought in hyperbolic discounting, we suggest the investigators consider the possibility of heterogeneity in time preference and inter-temporal decision making. Hyperbolic discounting by only a minority of consumers could lead to large market failures. Thus, for arguments of market failure in addictives consumption, for example, we see no need to demonstrate that hyperbolic discounting is universal. Both experimental and population studies could likely benefit from explorations of the behavior of sub-samples that would consider alternative mechanisms by which consumers discount the future.

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