MACS 30200

Literature Review

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Intertemporal Choice - Tradeoff between Money and Time

Intertemporal choices refer to decisions involving consequences and relative preferences - tradeoff between cost and benefits - that occur at different time points (Frederick, Loewenstein, & O'Donoghue, 2002). For example, a choice with two alternative options: $10 today versus $20 in a week. These intertemporal decisions involving tradeoff between money and time have been extensively studied across several academic domains including economics, psychology, marketing, decision-making science, and recently neuroscience. Intertemporal choices have several alternative names in these domains: *intertemporal discounting*, *time preference, delay discounting,* and *time discounting* (Doyle, 2013).

Discounted Utility Theory

The most widely used theoretical framework for studing intertemporal choices is the theory of discounted utility (Samuelson, 1937; Frederick et al., 2002), which uses a *discount rate* to address the lose value of delayed consequences. The discounted utility theory states that, the more delayed the consequence is, the more value the rewards lose, i.e., the higher the rewards are discounted. In other words, the higher the discount rate is, the greater the preference for earlier choices over later choices (Chabris, Laibson, & Schuldt, 2010). Discount rates can also be considered as a measure of impatience from a psychological perspective: the higher the discount rate is, the more likely that an individual would choose the earlier choice, which indicates the less patient he or she is.

Measuring Intertemporal Choices

Past research has measured intertemporal choices by eliciting preferences over various alternative choices obtained at different times. To be specific, the common experimental paradigm is *money-earlier-or-later* (MEL) task, in which individuals choose between a smaller, earlier monetary reward and a larger, later monetary reward (Marzilli Ericson, White, Laibson, & Cohen, 2015). The example mentioned at the beginning - $10 today versus $12 in a week - is a typical MEL task. Based on the MEL task paradigm, two main categories of methods are employed in measuring intertemporal choices: choice based and matching based (Urminsky & Zauberman, 2015).

Choice based measure. The choice-based measure (e.g., Kirby & Marakovic, 1996; Tanaka, Camerer, & Nguyen, 2010) presents individuals with a series of MEL tasks to elicit discount rates. For example, $10 today versus $12 in two weeks, $10 today versus $13 in two weeks… By increasing the monetary amount in the following binary choices, researches are able to identify the point in which individuals switch from the smaller, earlier option to the larger, later option, so that the discount rate can be derived. In this experiment paradigm, both monetary and time delay amount can be incremented to examine the switching point according to various experiment designs.

Matching based measure. Instead of presenting a series of MEL tasks, the matching based measure (e.g., Thaler, 1981; Malkoc & Zauberman, 2006) provides individuals with a sooner option such as $10 today, and then ask for their desired monetary amount at a later time such as in two weeks (e.g. $__ in two weeks), so that they are indifferent between the sooner and the later option. By asking individuals for a single response of the equivalent amount, researchers are able to derive the discount rate as well.

Modeling Intertemporal Choices

A vast literature in economics, psychology, and business have explained the way individuals trade off time and money by proposing different models with various characteristics. These models can be generally categorized into two groups: delay discounting models and heuristic models. The delay discounting models, which are based on the discounted utility theory, have dominated the research in intertemporal choices for a long time. In this paper, three important and typical delay discounting models are discussed: exponential model, hyperbolic model, and quasi-hyperbolic mode. The heuristic models, which are more recent developed, arouse researchers' interest due to the ability to address intertemporal choice anomalies better than the standard economic models. Three heuristic models are discussed in this paper: ITCH model (Marzilli, Ericson, et al., 2015), Trade-off model (Scholten & Read, 2010), and DRIFT model (Read, Frederick, & Scholten, 2013).

Since each model has various versions in the past literature, this paper uses the versions in Marzilli Ericson et al., (2015). The outcome is a binary variable: 1 represents the larger, later option is chosen, 0 represents the smaller, sooner option is chosen. In each of these models, the notation, *L(z)*, represents the inverse logistic function of z:

$$L(z) = (1 + e^{-z})^{-1}$$

P(LL) represents the probability that individuals prefer the larger, later option over the smaller, sooner option. The variable *a* represents the logistic scaling parameter. The notation *I(x)* represents the indicator variable that is 1 if x is true and 0 otherwise. x_1 and x_2 are the variables of monetary amount; t_1 and t_2 are the variables of time amount.

Delay Discounting Models

Exponential model. The first well-known standard economic model is the Discounted Utility Model (Samuelson, 1937), which is also called Exponential discounting model. In this model, intertemporal preferences are governed by the discounted utilities of the options. To be specific, the utilities are exponentially discounting as a function of the delays to the outcomes. Exponential discounting model, which assumes the constant discount rate, ensures consistency in the treatment of time, so that intertemporal choices will not change merely due to time changes (Strotz, 1955). The functional form of the Exponential model is:

$$P(LL) = L(a\ (x_2\delta^{t2} - x_1\delta^{t1}))$$

Hyperbolic model. Hyperbolic discounting model is motivated by the common difference effect (Loewenstein & Prelec, 1992). Instead of assuming that constant exponential discounting rate as the Exponential model, this model suggests that there is more discounting over an earlier interval that the later interval. The options' values are hyperbolically discounted as a function of the delay to the outcomes. The functional form of the Hyperbolic model is:

$$P(LL) = L(a\ (x_2(1+\alpha t_2)^{-1} - x_1(1+\alpha t_1)^{-1}))$$

Quasi-hyperbolic model. Quasi-hyperbolic discounting model, which is nested on the Exponential model, employs new features to account for the *present bias* (O'Donoghue & Rabin, 1999): there is more discounting over an interval that begins now than one that begins later. The functional form of the Quasi-hyperbolic model is:

$$P(LL) = L(a\ (x_2\beta^{I(t2>0)}\delta^{t2} - x_1\beta^{I(t1>0)}\delta^{t1}\ ))$$

Heuristic Models

Since standard economics models cannot account for some empirical regularities – intertemporal choices anomalies, researchers develop heuristic models. The anomalies of intertemporal choices (Loewenstein & Prelec, 1992; Laibson, 1997) include but are not limited to: (a) *reversal of preference*: individuals are more impatient for shorter time horizons than for longer intervals; for example, an individual prefers $10 today over $12 tomorrow, but he/she prefers $12 in a year plus a day over $10 in a year (Benhabib, Bisin, & Schotter, 2010); (b) *magnitude effect*: instead of constant discounting rate, the empirical discounting rate is observed to decline with the amount to be discounted (Thaler, 1981). The heuristic models are developed based on attribute-based tradeoffs, which are different from alternative-based discounting.

ITCH model. ITCH model, which stands for *intertemporal choice heuristic* model, is based on psychological principles rather than economic theory, and inspired by attributed-based models. As Marzilli Ericson et al., (2015) argues that, "the ITCH model implement four basic psychological principles: (a) each option is compared to a reference point (Kahneman & Tversky, 1979); (b) comparisons are performed in both absolute terms (by subtraction) and relative terms (by division; Thurstone, 1927); (c) comparisons are performed independently along the monetary and time dimensions (Lichtenstein & Slovic, 1971); and (d) the results of these comparisions are then aggregated linearly using a set of decision weights (Busemeyer & Townsend, 1993)." The functional form of the ITCH model is:

$$P(LL) = L(\beta_I + \beta_{xA}(x_2 - x_1) + \beta_{xR}\frac{x_2 - x_1}{x^*} + \beta_{tA}(t_2 - t_1) + \beta_{tR}\frac{t_2 - t_1}{t^*})$$

Trade-off model. Scholten & Read (2010) develop a model in which "people make intertemporal choices by weighing how much more they will receive or pay if they wait longer against how much longer the wait will be, or, conversely, how much less they will receive or pay if they do not wait longer against how much shorter the wait will be." The Trade-off model accounts for several anomalies that the delay discounting models cannot address. The functional form of the Trade-off model is:

$$P(LL) = L(a\,((\frac{\log(1+\gamma_x x_2)}{\gamma_x} - \frac{\log(1+\gamma_x x_1)}{\gamma_x} - k(\log(1+\gamma_x t_2) - \frac{\log(1+\gamma_x t_1)}{\gamma_x})))$$

DRIFT model. In order to answer the question that "People prefer to receive good outcomes immediately rather than wait, and they must be compensated for waiting. But what influences their decision about how much compensation is required for a given wait", Read, Frederick, & Scholten (2013) propose the DRIFT model, whose functional form is:

$$P(LL) = L(\beta_0 + \beta_1(x_2 - x_1) + \beta_2\frac{x_2-x_1}{x^*} + \beta_3\frac{x_2}{x_1}^{\frac{1}{t2-t1}} + \beta_4(t_2 - t_1))$$

All these models have both their own unique advantages and disadvantages. In the following, I am going to compare these models.

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