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THE EVOLUTION OF INTERTEMPORAL CHOICE THEORY

FROM AN INTER-DISCIPLINARY PERSPECTIVE

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Abstract

Over time economic inquiry has focused on the determinants of human behaviour and how these influence the decisions of economic agents. This inquiry evolved from the broad philosophical approach of the classical economists into neoclassical economics with its limiting assumptions concerning human motive. Concerns that the neoclassical economics lacked realism in this area contributed to the development of behavioural economics and more recently its involvement with cognitive psychology. A recurring theme through all of these phases has been the continued interest in explaining the inconsistency displayed by agents when making intertemporal choices. Research indicates choices made by agents vary considerably depending on the time frames in which the decisions are made. The choices made under these conditions may deviate substantially from the theoretical alternatives that are consistent with the assumptions of rational behaviour.

A common theme which prevails throughout this research is the degree to which individuals modify their decisions based on perception of future time. Even though it is reasonable to assume an agent will want to maximize available choice options, the research shows that the human thought process is not consistent over time and is subject to the constraints imposed by their cognitive and psychological limitations. This paper will explore some of the significant developments in the history of intertemporal choice theory and will examine the evolving body of research emanating from behavioural economics and cognitive psychology. It will be argued that intertemporal choice behaviour in humans has the potential to significantly influence economic outcomes however its theoretical application is constrained because it remains essentially a static analysis.

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(KEYWORDS: Intertemporal choice, delay discount rate, hyperbolic discounting, dual systems, cognitive psychology, time perception, neuroeconomics, addiction, commitment devices)

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Introduction

This paper will review the literature associated with the development of intertemporal choice[1] theory particularly from the perspective of its adequacy in interpreting different forms of human behaviour under varying decision making conditions. The implications for economic policy makers will also be discussed where agents need to make decisions under intertemporal constraints.

The traditional neoclassical starting point for understanding the behavioural motives of an economic agent is to assume that self-interest is best served by objectively focusing the cognitive[2] process on maximizing utility. This assumption is considered to be a manifestation of rational behaviour (Simon, 1986).

The assumed characteristic of such behaviour is the ability of the agent to be in possession of all physical and logical options available in existence and to employ them in the decision making process. In addition it is also assumed that the agent is able to perfectly compute and preferentially rank the probable utility outcomes of all of the choice options available (Simon, 1986).

Herbert Simon contrasted the explanation of the notion of rationality between that of economists and psychologists. "Economics has almost uniformly treated human behaviour as rational. Psychology on the other hand, has always been concerned with both the irrational and the rational aspects of behaviour" (Simon, 1986:s209). Essentially he expressed the view that the domain of rationality referred to by economists was essentially narrow and excluded aspects of behaviour, which from psychologist's point of view were not necessarily irrational, but characteristic of a broader view of human behaviour. He concluded that behaviour,

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[1] A broad definition – "Intertemporal choice is used to describe any decision that requires trade-offs among outcomes that will have their effects at different times" (Read, 2003). From a computational perspective - "For each course of action, compute the present value of the consequences, using a personal discount rate. Then choose the action that has the highest present value" (Prelec and Loewenstein, 1997:97).

[2] Cognitive is a term referring to the mental processes involved in gaining knowledge and comprehension, including thinking, knowing, perception, remembering, judging and problem-solving. These are higher-level functions of the brain and encompass language, imagination, perception and planning, through experience (Concise Oxford Dictionary, 2006).

despite how externally delusional, is motivated by a thought process which includes internal reasoned judgements based on perceptions of the external world.

Many of the behavioural traits alluded to in Simons' analysis must result in decisions that have economic consequences and therefore must be included in the total set, which forms the group type 'rational economic man'. To do otherwise would be to impose a subjectivity concerning that which is rational and thus restrict any explanations or predictions from derived models to a theoretical sub-set of ideal type economic actors.

This paper's focus on intertemporal choice will include the findings identified by economists relating to the behavioural characteristics that influence the output of the decision making process when comparisons between discrete time elements are discussed. Decisions that have consequences in multiple time periods are intertemporal choices. Economic analysis that focuses on the study of intertemporal choice decisions deals with explanations as to why economic agents rank utility levels derived from economic activities in the present, at higher values than the same activities conducted in the future. This approach involves the use of Discounted Utility (D U) and derived models to analyse and potentially predict expected levels of utility and the associated discount rates under varied behavioural conditions (Chabris, Laibson and Schuldt, 2008).

In this paper an historical review of the intertemporal choice literature will be presented. This will include a discussion on the multi-discipline approach towards explaining intertemporal behaviour involving economic theory, cognitive psychology and neurological research.

The following format will be used to develop an understanding of the topic.

In Part 1 the evolution of intertemporal choice theory will be reviewed from the early work of Rae, Jevons, Senior and Bohm-Bawerk, including the pioneering D U modelling work of Fisher and Samuelson and then to more recent areas of research including the development of the hyperbolic discounting model introduced by Strotz. This review will reveal how intertemporal choice theory developed to the point where it was realized that besides economics methodology and understanding of cognitive psychology would be required to adequately describe the phenomena.

In Part 2 the development of a cognitive psychological approach towards explaining intertemporal choice will be discussed. This will include how hyperbolic discounting

theory was integrated into this field of study. The review will focus on developing an understanding of how the cognitive process defines the extent of the boundaries within which humans are capable of making decisions. This will include identifying the key components of the human thought process that determines intertemporal choice responses in subjects. The techniques used to scientifically test these cognitive theories will also be discussed.

In Part 3 the significance of intertemporal choice behaviour in determining economic outcomes will be discussed in the context of economic policy formation. This will involve presenting two case studies to demonstrate the significant impact on mainstream economic policy by aspects of intertemporal choice behaviour that will be discussed in this paper. Finally based on the review of the research literature presented, the discussion will critically explore the structure of intertemporal choice theory and in particular how uncertainty concerning future prospects, limits the theories ability to make certain predictions.

Part 1 - The Historical Development of Intertemporal Choice Theory

1.1 Foundations Created by Early Economists

> *When we consider the condition of the great, in those delusive colours in which the imagination is apt to paint it, it seems to be almost the abstract idea of a perfect happy state. It is the very state which in all our waking dreams and idle reveries, we had sketched to our-selves as the final object of all our desires (Smith, 1759:46).*

Adam Smith wrote "The Theory of Moral Sentiments" sixteen years before his landmark work "An Inquiry into the Nature and Causes of the Wealth of Nations". The above quote presents an abstract view on the introspective nature of human desire and stands in contrast to the vast body of economic theory that was to develop over the next 230 years based on his later work. The predominant view that later emerged in the form of the neoclassical school of thought assumed away the existence of sentiment through the assumption of rationality in the course of maximizing benefits.

Lionel Robbins, an influential and noted sceptic of the inclusion of theories of psychological motivation within the scope of economic inquiry (Angner, Loewenstein, 2006:10), acknowledged the controversy surrounding this issue. He was asked at a series of London School of Economics lectures between 1979 and 1981, if there was in his view a contradiction between Smith's theses expressed in "The Theory of Moral Sentiments" and those relating to rationalistic self-interest as advanced in the "Wealth of Nations". Robbins refers to that part of Smith's views expressed in the former work, concerning "the effects by an impersonal spectator" (Smith, 1759:20) that exists within the mind of the actor, arbitrating on an impartial basis as to what constitutes morally acceptable behaviour. Robbins concludes that in his opinion there was no conflict, as he was in no doubt that the "impartial spectator" would judge "that social utility was best served by the exchange relationship", which was based on the premise that "the impersonal relationship of exchange … provides the incentive to division of labour" bringing about the most efficient outcome for society (Robbins, 2000:133-134).

These comments, illustrate the contrast in views between those of the classical school which acknowledged the central role human behaviour plays in economic decisions and those of the

predominant post-war orthodoxy reflected in the conclusions by Robbins. Robbins' approach seems to suggest that the debate should be restricted to a narrow perspective focused on the assumption of rational self-interest. This theme will be further expanded as the development of the theory is discussed, particularly in the context of the behavioural aspect of intertemporal choice.

An important contemporary of Smith was the Scottish classical economists John Rae. Although he was not widely recognized within his own generation, his work, "The Social Theory of Capital", significantly influenced the later works of Senior, Jevons, Böhm-Bawerk and Fisher, (Frederick, Loewenstein and O'Donoghue, 2002).

Rae was interested in why the wealth of various nations accumulated at different rates. In this respect he pursued the same line of interest as Smith, but he also introduced a new area of inquiry. This involved some distinctly psychological insights concerning the interplay of intertemporal considerations on the decision making process that involved the rate at which capital accumulated. Rae was interested in what motivated agents into deciding how labour should be allocated between activities involved in the present consumption of goods, opposed to the allocation of labour to produce capital goods for later consumption (James, 1951).

Rae differed in this regard from Smith who focused on the division and specialization of labour. Robbins (2000) commented on the approach adopted by Adam Smith in explaining the causes of how labour is allocated. Smith contended that at any point of time, the level of accumulated capital and in particular the proportions that exist between stocks for immediate consumption and those to be gradually consumed, determine how labour is allocated. The division of labour and thus its level of utilization was therefore a function of the investment decisions that firms make between the allocations of capital towards the production of consumer goods, opposed to increasing the stocks of productive capital goods. He went on to discuss how Smith considered that such allocations were influenced by the savings decision of labour. "Capitals are increased by parsimony" and "diminished by prodigality and misconduct" (Robbins 2000:143-145).

Rae did not agree with Smith's explanation that the different rates of capital accumulation could be explained purely by the savings rate alone. Rae referred to the "effective desire to accumulate" (Rae, 1834:119) requiring the sacrifice in the present to achieve a greater good in the future. He introduced the concept of "instruments" which are produced entirely by the

application of labour and measured at a standard rate (Rae, 1834:85). Instruments are exhausted when their utility expires. Instruments such as consumables are exhausted almost immediately. Other instruments are transformed in combination with others to produce capital goods which are then exhausted over an extended period of time, or alternatively their life is extended by the application of subsequent instruments (Rae, 1834:85). This would take the form of maintenance and/or improvements.

Warren James stated that Rae was concerned with the motivation that determined the degree to which a person was prepared to sacrifice current consumption, "current good" for a future good. Rae noted that the future yield had always to exceed "the present sacrifices" (James, 1951:147) when creating an instrument, otherwise there would never be any incentive for their production. This would seem to correspond to the contemporary definition of intertemporal choice outlined in the introduction.

Of additional significance are Rae's explanations of conflicting behavioural characteristics of agents. He discussed the "determination to sacrifice" a present consumption to derive greater satisfaction in the future. He also noted that:

> If life were to endure forever, were the capacity to enjoy in perfection all its goods, both mental and corporeal, to be prolonged with it, and where we guided solely by the dictates of reason, there could be no limit to the formation of means for future gratification, till our utmost wishes were supplied (Rae, 1834:119).

He went on to suggest that the factors that limit such rational but ethereal behaviour, are the prospect of an individual's own mortality and their constant desire to partake in the particular consumption activity in the immediate future. When Rae states that "the prospects of future goods, which future years may hold out to us, seem at such a moment dull and dubious", he implied that the uncertainty that exists when contemplating the future and the need for immediate gratification, "pleasures as may now be enjoyed, generally awaken a passion strongly prompting to the partaking in them", he clearly gives his perspective on the behavioural characteristics of choice (Rae, 1834:120). Rae's work represents an important stage in the evolution of economic thought which significantly influenced a series of future economists.

W. Jevons and his son H. Jevons derived from Rae's work the view that postponement of gratification occurred as a result of an increase in "anticipal" utility which would compensate

the deferrer for a reduction in current consumption utility (Fredrick et al 2004:164). Jevons Senior approached the problem from a marginalist perspective by assuming that total marginal utility is derived by distributing consumption over time. He proposed that an agent would assign a factor to each successive time period equivalent to the probability of consumption actually occurring and given that future consumption might never happen, an agent would exhibit a rational preference for current over delayed consumption (Loewe, 2006:80).

Nassau Senior in his book on the "Political Economy" discussed the role of "abstinence" in ensuring a portion of the current product of labour is directed towards the creation of future means of production rather than current consumption. He discussed at length the role of human will power in this process in countering the tendency of people to want to consume now rather than wait. "To abstain from enjoyment which is in our power or to seek distant rather than immediate results, are among the most painful exertions of human will" (Senior, 1854:60).

1.2 Böhm-Bawerk - The Value of Future Goods

The work of the classical economists was influenced by the philosophical approach derived from moral philosophy.[3] Economic methodology evolved towards providing a more positivist analysis of economic behaviour. Böhm-Bawerk was a major figure in this process. In his work "A Positive Theory of Capital", he presented an extensive study on the nature of interest in all its different forms. At the centre of his extensive thesis was the following proposition. "Present goods are, as a rule, worth more than future goods of like kind and number. This proposition is the kernel and centre of the interest theory which I have to present" (Bohm-Bawerk, 1891:237).

In the chapter titled "Underestimate of the Future", Bohm-Bawerk contrasts the behaviour of sophisticated societies in which the provision for future wants is acknowledged through the allocation of labour to the production of capital goods, receiving a much higher priority than

[3] On moral philosophy (ethics): The discipline concerned with what is morally good and bad, right and wrong. The term is also applied to any system or theory of moral values or principles (Singer, Encyclopaedia Britannica, 2011).

that which occurs in primitive societies. However he concedes that all people are susceptible to varying degrees, to the undervaluing future goods. He referrers to the psychological relations that affect our feelings and judgements and the fact that these are obscure factors which cause distortions in the way future events are perceived. Bohm-Bawerk wrote,

> Without meaning to fore-stall the pronouncement of the psychologist, who seem to me more competent to decide on both questions than the economists, venture to think that this phenomenon rests, not on one ground , but on the joint action of no less than three different grounds (Bohm-Bawerk, 1891:254).

He went on to outline these separate influences. Firstly he discusses the limitations of the imagination which he says is either due to a lack of ability to abstract future events or alternatively an inherent laziness to bother discerning future wants. This leads to a distortion in the valuation of future goods which in turn will influence current allocations. Secondly he suggests that when decisions are taken to act in the present, even though this may result in a future welfare loss, such actions are often undertaken by individuals in all conscience of the consequences. These decisions may occur with feelings of guilt or regret. He gives the example of a deed that is postponed to accommodate a current pleasure whilst knowing the postponement will yield to a greater future loss of utility[4] (Bohm-Bawerk, 1891:255).

Finally he discusses the effect referred to by Rae, where the prospect of one's own future mortality may to varying degrees, affect the probability weighting of the certainty of future events. He provides the example that it may be objectively correct to expect a future return with almost 100% certainty from a particular instrument, but the probability that one might survive to enjoy the return might not be so certain. Bohm-Bawerk expresses the prospect of an uncertain future in this way, "The disregard of a future so uncertain not seldom finds drastic expression in the mad extravagance which seizes people in such circumstance" (Bohm-Bawerk, 1891:256).

A common perspective in all of these early works is the reference to several sets of potentially conflicting behavioural tendencies influencing the decision making process. Some of these characteristics could be classified as typical rationalistic self-interest type behaviour, demonstrated by the desire to accumulate for one's own future benefit, or perhaps as a gesture of benevolence towards one's own family. In contrast, reference is also made to the

[4] This topic is covered particularly well in an essay by Akerlof titled "Procrastination and Obedience" where repeated errors involving time inconsistent behavior may cumulate into large losses. (Akerlof, 2005;209-231)

psychological desire to consume now to gain immediate gratification or to consume sooner than later as a result of the uncertain prospects relative to one's own continuing existence into the future. Frederick et al. refers to these different perspectives as anticipatory-utility. He explained that intertemporal choice behaviour is attributed to "people's abilities to imagine the future and to differences in situations that promote or inhibit such mental images" (Frederick et al 2002:354), also abstinence which results in different intertemporal responses, brought about by the psychological discomfort triggered by a confrontation occasioned by self-denial. This condition they conclude would be associated with high rates of time discounting, brought about by the pain caused by the self-denial.

These conflicting desires are able to be conceptualised in a framework which exhibits standard characteristics of intertemporal irregularity with regard to the allocation of resources by agents as a group. In addition as these works also recognize different propensities by agents to moderate these conflicting desires, the degree of intertemporal irregularity will be inconsistent among members of the groups. Bohm-Bawerk's direct reference to the psychological factors that influence intertemporal behaviour is an early example of the cognitive perspective. Clearly the dimensions of such a set of potential behavioural outcomes requires economic models capable of encompassing all probable outcomes without being significantly limited by unrealistic assumptions. The development of such models would be the challenge for the theorists that were to follow.

1.3 Irving Fisher – Interest Rate Theory and Subjective Value

In the preface to his 1907 work "The Rate of Interest", Irving Fisher stated that apart from the work of "Rae, Bohm-Bawerk and Laundry and a few others" (Fisher, 1907:vii), very little had been done to advance the theory of interest over the previous two thousand years. In particular he refers to the central role that time-preferences play in understanding the function of interest in decision making theory. Fisher refers to a "premium in the exchange between present and future goods" and the "(percentage) excess of the present desirability of present goods over the present desirability of an equal amount of future goods" (Fisher, 1907:88). Expanding on the meaning of "goods", Fisher suggests that all outlays on goods whether consumer goods and services or investment instruments, are able to be viewed from the perspective of preferences for current income over future income. Activity that yields a

benefit now is valued higher than an investment in a future activity and its corresponding future benefit. Fisher provides the example of a weaver who prefers to sell cloth sooner than later and thus derive an income which can be consumed sooner and the ultimate customer who would prefer to purchase the clothing sooner so as to experience the resultant utility in the present (Fisher 1907:90).

Expanding on this theme, Fisher focused on the characteristics of the income stream[5] that individuals experience throughout their lives. In an earlier work "Nature of Capital and Income", he defines income in these terms;

> We define subjective income, then, as the stream of consciousness of any human being. All his conscious life, from his birth to his death, constitutes his subjective income. Sensations, thoughts, feelings, volitions, and all psychical events, in fact, are a part of this income stream (Fisher, 1906:168).

He contended that final income could be viewed as being composed of physical and psychical elements, or alternatively defined, the objective and subjective. For example the consumption of food involves the physical destruction of the material and its subsequent integration with the body together with the psychological sensations and enjoyment associated with the process of eating.

Fisher defined time-preference as "a preference for early enjoyable income compared with remote enjoyable income", which depends on the future income-stream and in particular how this income stream is distributed through time. He refers to the concept as "the time-shape of the income stream" (Fisher, 1907:92), which is reflective of the rate at which an individual's abundant plentiful supply of future income might be sacrificed to receive a relatively small fraction of present income. The schedule rate at which the time-preference is distributed depends on the quantum and probability at each instant "of the entire collection of income-elements" (Fisher, 1907:94).

The shape of this time-preference according to Fisher is determined by four elements:

- The volume of the income stream.
- The distribution over time. When it is abundant and when it is in short supply.

[5]The term income is used here in a very wide context.

- Its composition. That is its objective and subjective characteristics.
- The probability of the eventuality of its "constituent elements" occurring. (Fisher; 1907:94)

He also provided an interpretation on those characteristics of human nature which he referred to as "the personal equation" (Fisher, 1907:103). He argued that these characteristics shape individual time-preferences. These he classified under the following headings (Fisher, 1907:103-106)

- Foresight. The greater this ability is exercised the less the rate of time-preference.
- Self-control. That is the ability to control subjective desires.
- Habit. This includes cultural conditioning.
- Life expectancy. This topic is similar to Rae's and Bohm-Bawerk's observations concerning the prospect of continuing mortality and the resultant affect on preferences.
- Interest in the Lives of Others. Again following the observations of Rae and Bohm-Bawerk. The emotional effect of wanting to provide for the future of others particularly family.

Having laid the foundations for a theory of time preference, Fisher reflected on the practicality of creating a mathematical expression which could incorporate the critical elements of what he proposed. He described the prospect of achieving such an expression in the following way. "A geometric representation therefore, of the dependence of time-preference on the various magnitudes which characterize income, would be impossible" (Fisher, 1907:113).

Fisher went on to explain that, unlike expressions which represented a single curve such as price and demand schedules which only involve a single order of magnitude, the causes of income preferences over time "would need a space of *n* dimensions" (Fisher, 1907:113).

Despite the limitations identified by Fisher in seeking a mathematically based explanation for an individual's time preferences, he proposed that in the aggregated economy forces

generated by financial markets tend to "bring into equality the rates of preference in different minds" (Fisher, 1907:117). It was only the technical limitations of these markets[6] that restricted their ability to determine absolute equality in comparative time-preferences.

The assertion of the equalization of preference rates of individuals is based on the assumption that an agent irrespective of their preference characteristics, will initially possess a certain and rigid view of the composition of their future income stream. It is also assumed that they are able to exchange any part of that future income stream through the medium of the loan markets and that the only method of altering the income stream is by effectively buying or selling future segments. This process will alter the "time-shape of the incomes of borrower and lender" (Fisher, 1907:118), which in turn will modify the time-preferences of the parties causing the market to approach equilibrium. Individuals, who have a rate of time preference above or below the market interest rate, will adjust the time-shape of their income stream by buying or selling future segments. For example an individual whose time preference is greater than the current market interest rate, will sell some of their surplus future income stream that is, borrow, to supplement their current scarce income and conversely another individual with a time preference lower than the market rate will exchange surplus current income (lend) for a greater stream of future income.

1.4 Lionel Robbins – Insights into Economic Methodology

The further development of intertemporal choice theory was to some degree hindered by the prevalent view that existed in economic methodology at the time.

Lionel Robbins in "An Essay on The Nature & Significance of Economic Science" wrote how economic methodology treated the psychological aspects of the individual. "Here we are sentient creatures with bundles of desire and aspirations with masses of instinctive tendencies all urging us in different ways to action. But the time in which these tendencies can be expressed is limited" (Robbins, 1932:13).

He went on to say that analytical economics does not entirely rest on psychology however it unquestionably could not be excluded.

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[6] The technical limitations to which Fisher refers, is the unequal ability of agents to access loan markets due to collateral considerations.

"The subjective or psychological theory of value: and, as we have seen, it is clear that the foundation of this theory is a psychical fact, the valuations of the individual" (Robbins, 1932:86-87).

Interestingly he also wrote that partly as a result "of the influence of Behaviourism" and the need "to secure the maximum possible austerity in analytical exposition, there have arisen voices urging that that this framework of subjectivity should be discarded." (Robbins, 1932:86-87). Referring to those voices wishing to impose pure positivist views on economics, he commented on the influence they had on those that rejected logical positivism. He defined this group as possessing "an attitude which is very frequent among economists who come under the influence of Behaviourist[7] psychology, or who are terrified of attack from exponents of this queer cult" (Robbins, 1932:87). It is not completely clear here if he was referring to the logical positivists or Behaviourists as belonging to that 'queer cult'. Either way in context of the direction intertemporal theory was developing, these observations were very prophetic.

1.5 Keynes - Uncertainty

The advent of the Great Depression caused a fundamental change in the way economic policy was implemented. The move to greater financial regulation as a result of the excesses of the financial intermediaries and the increased role of central planning in setting economic policy, created the conditions for a major shift in methodological sentiment. A major influence emerged in the form of John Maynard Keynes and his views on the role that certainty plays in economic policy.

Keynes in his "General Theory of Employment" (1936) wrote about the role expectations played in the long run and how confidence was a function of the probability that our forecasts were accurate under conditions of uncertainty. He also referred to two prime components of those forecasts. He used the term "speculation or the activity of forecasting the psychology of the market and the term enterprise for the activity of forecasting the prospective yield of assets over their whole life" (Keynes, 1936:158). He also commented that it was the

[7] Behaviourist methodology developed in the first half of the 20th century. Pavlov and Skinner had a major influence. The field was concerned with the effect of conditioned responses to stimuli viz 'Pavlov's dog". The doctrine which evolved included: Psychology is the science of behaviour not the science of the mind and incidents of behaviour are caused by conditioned responses stimulated by the occurrence of external events.

prevalence of certainty that influenced which of these two factors dominated at any particular time. He concluded that human decisions affect the future and cannot be subject to strict mathematical expressions as the basis for the calculations that as yet did not exist and that "our rational selves choosing between the alternatives as best we can, but often falling back for our motive on whim or sentiment or chance" (Keynes, 1936:163).

1.6 Paul Samuelson and Discounted Future Utility

Paul Samuelson's 1937 paper "A Note on Measurement of Utility" introduced the concept of Discounted Utility (DU) into the field of intertemporal choice research. Although Samuelson declared some reservations concerning the appropriate interpretation of the model, it was quickly interpreted in a wide context as a generalized expression of DU to be used in such areas as public policy and also as a descriptive expression of actual behaviour (Fredrick et al., 2002). His paper presented a model that provided a framework which under strict assumptions produced a functional expression for intertemporal choice over future time increments. Where Fisher's First and Second approximations and the accompanying use of indifference curves restricted his analysis to a limited projection of future time periods, Samuelson's DU model presented no such restrictions other than the limitations inherent in the assumptions. The focus of the earlier writers towards an analysis of the psychological characteristics of agents towards time preferences and the consequential infinite set of possible outcomes were "compressed into a single parameter, the discount rate" (Frederick et al, 2002,351).

With direct reference to the actual paper, Samuelson clearly states that his intention was not to further the "inductive investigation" of utility measurement "a subjective quantity", but to construct an ideal type where observable behaviour may "render open *unambiguous* inference the form of the function which he is conceived as maximising" (Samuelson, 1937:155).

Samuelson hypothesised that given four specific assumptions it was theoretically possible to determine a theoretically accurate measure of the marginal utility of an individual's money income, where tastes and prices remained constant over the subject period (Samuelson, 1937:155).

Samuelson presented the key assumptions as follows.

1. "*Utility is uniquely measurable as, in consequence, is marginal utility*" (Samuelson, 1937:156).

Given fixed prices the variations in money income will create a time shape profile consisting of the marginal utility of money income over a particular period of time. Marginal utility is expressed as the rate of utility per dollar.

2. "*During any specified period of time, the individual behaves so as to maximize the sum of all future utilities, they being reduced to comparable magnitudes by suitable time discounting"* (Samuelson, 1937:156).

Samuelson refers to this assumption as being axiomatic and not subject to proof, as otherwise any observable behaviour might be attributable to the assumption and not related to the maximization of future utilities.

3. "*The individual discounts future utilities in some simple regular fashion which is known to us*" (Samuelson, 1937:156).

Here in the first instance it is assumed the future rate of discount in respect to utility is constant. This factor might reflect zero time preferences or even reflecting that future utility is valued at a premium.

4. *"We define an ideal set of experimental conditions under which the individual under observation must act"* (Samuelson, 1937:156).

Fredrick et al, (2002:355-356) interprets Samuelson's utility measurement functions as follows. Under the given assumptions, an agent's intertemporal preferences may be expressed by an intertemporal utility function in the form $U^t(ct,\ldots\ldots,c_T)$ where $U^t(ct,\ldots\ldots,c_T)$ and as such are the intertemporal profiles of the agent. This can be further expanded into a discounted utility model over time T in the form:

$$U^t(c_t,\ldots\ldots,C_T) = \sum_{k=0}^{T-1} D(k)u(c_{t+k}), \quad where\ D(k) = \left(\frac{1}{1+\rho}\right)^k.$$

The function $u(c_{t+k})$, in this case can be regarded as the agents cardinal instantaneous utility function expressed in period (c_{t+k}) and $D(k)$ their discount function that expresses the weighting attributed to utility in period t. ρ is the agent's rate of time preference (personal discount rate) is representative of the entire set of personal psychological characteristics that might influence their intertemporal choice behaviour.

Samuelson hypothesised that when the rate of interest (on unused capital) equals the individual's discount rate, the value of remaining capital will not be conserved due to the effect of the amortization of the capital. The agent would allow this attrition to occur "in such a way that it will provide him with a steady income over the finite period under consideration" (Samuelson, 1937:159). Here he equates a "finite period" with the individual's life span or additionally those of the agent's immediate heirs, if he or she was of a benevolent inclination. The "datum" for each agent is the interest rate against which their personal discount rate was assumed to be referenced at "every instant of time" (Samuelson, 1937:159). At that instant it was assumed that the agent's level of satisfaction depended only on current consumption relative to their personal discount rate compared to the datum.

Samuelson further observes that as the individual progresses through time *" there is a sort of perspective phenomenon in that in his view of the future in relation to his instantaneous time position remains invariant"* (Samuelson, 1937:160).[8] He provides an example of how this time relative effect is countered by people entering into forced savings instruments. However he acknowledges in reality the invariance of individual perspective at any point of time is subject to an array of personal influences without actually mentioning the word psychological. Most significantly he went on to point out that the model presented would be valid whether the discount rate remains the same from the beginning of the period (invariant), or is reassessed periodically during the balance of the time frame. This implies that at any point of time, when any aspect of the budget variance occurs as a result of intertemporal adjustments between stocks and flows, the discount rate would also change.

Samuelson concludes his paper with a caveat that, "any connection between utility as discussed here and any welfare concept is disavowed" and that any further statistical analysis

[8] Strotz, (1955:165), in an early paper on Hyperbolic Discounting acknowledged that Samuelson (1937:160) had alluded to the effect of time inconsistent preferences.

which may influence policy "deserves the impatience of modern economists" (Samuelson, 1937:161).

According to Fredrick et al, (2002) this particular paper had a profound influence on future lines of research into intertemporal choice. Its concise and succinct formulation resulted in the paper being established as a template for ongoing intertemporal research regardless of Samuelson's own reservations.

In his 1970 Nobel Memorial Lecture, Samuelson reflected on certain principals in analytical economics and as the title suggests, the concept of "a maximum system" (Samuelson 1970:69) in economic theory. He explains how the mathematical theory associated with "an entropy-maximizing thermodynamic system" (Samuelson, 1970:69), in physics and in particular the application of LeChatelier's Principal[9], was derived and applied to his own research. The method adopted was to solve for a maximizing system, where there are a large number of input variables *n*, for which exists interdependencies. At equilibrium and holding *n*-1 variables constant, a single variable input is changed. The system initially in disequilibrium will move to a new steady state but will cause the quantum of other variables to change and thus mathematically reveal the interdependencies within the system.

Samuelson analysed the feasibility of integrating static and dynamic methods of analysis. In relation to time and intertemporal choice, the challenge was to develop a model which would connect the output from a static equilibrium analysis to the preferences the agent revealed. This would find expression through the discount rate and provide a framework to predict the conditions which exist once a new equilibrium position was attained (Samuelson, 1966:613; as cited by Feiwel, 1982:7).

In this context, changing states in the present (the disequilibrium) would cause the agent to try and conceptualize changing prospects for the future. The limitation that would seem to restrict the DU models ability to provide realistic explanations of an agent's likely behaviour in re-ordering of intertemporal choice options would be the *a priori* nature of the personal discount rate. That is the rate is reflective of the historical behaviour of the agent and the model requires the assumption that such behaviour is in effect static in respect to the future. The

[9] Samuelson's definition of LeCatelier's principal: If an external constraint is placed on an equilibrium system, the equilibrium shifts to absorb or resist or adjust to or minimize the change. (Samuelson, 1970:67)

very nature of the assumption adopted, that is behavioural characteristics are fixed[10], would seem to be unrealistic. This observation is made reflective of Samuelson's maximization theory, where the related elements of a system subject to equilibrium are of a quantitative nature. In fact if we revert to the physical sciences and the source of the theory, we deal with real physical phenomenon. The difficulty for theories of intertemporal choice is that although it is reasonable to assume an agent will want to maximize their utility, it is not so clear if the relationships in the "system", in this case the human thought processes, are consistent over time.

Lowenstein expressed this limitation in these terms, "Stationarity [sic] and intertemporal independence, imply that any representation of preferences over temporal prospects can be monotonically transformed into a discounted utility function" (Lowenstein, 1992: 21). This implies that future preferences tend to be constant irrespective of the various contemplated elapses of time over which preferences are being considered.

From the perspective of the predictive ability of DU modelling, there are extensive case studies of observed human intertemporal decision behaviour which do not support predicted symmetrical outcomes (Thaler, 1981; Benzion, Rapopart and Yagil, 1989; Pender, 1996). For example people display asymmetric tendencies towards speeding up or deferring consumption at different times. They also tend to discount losses at a lower rate than gains. People also can display a need to finalize unpleasant experiences sooner rather than later, therefore reducing the effects of negative anticipation (Lowenstein, 1992). All of the above conditions are able to be associated with the psychological aspects of human behaviour

Samulson's DU model was developed in an attempt to provide a simple model which would describe the intertemporal characteristics and the time shape of preferences in a mathematical form. However the model did not sufficiently describe or come to terms with the various psychological forces at play. The result was a model, the descriptive capacity of which was limited to a symmetrical exponential discount expression which did not accord with observable human behaviour. The renewed acceptance by economists that psychological characteristics are not able to be separated from intertemporal decision analysis has resulted in

[10] The assumption previously referred viz. 3 "*The individual discounts future utilities in some simple regular fashion which is known to us*".

the development of models which seek to provide increased levels of realism in their description of human behaviour.

1.7 Strotz - Dynamic Utility

Robert Strotz wrote a paper in 1955 "Myopia and Inconsistency in Dynamic Utility Maximization" in which he attempted to reconcile conflicting characteristics of intertemporal choice behaviour and the likelihood that agents initial decisions would be modified over time. However he did not address these characteristics in any direct psychological context, preferring to categorize them under the following headings: "Spendthriftiness, the deliberate regimenting of one's future economic behaviour – even at cost" and "Thrift" (Strotz, 1955:165).

Strotz referred to an agent imagining a consumption plan for the future with the goal of maximizing utility in the present but within budget constraints. At that point of time the plan would represent a static set of preferences. He contended that there was no certainty that the agent would maintain that view over time even though from the current static perspective they were committed to the plan they had envisaged. The agent was in fact most likely to deviate from the optimal plan in the case of a "spendthrift". Alternatively where the person was a "rational individual", they would either pre-commit to some financial instrument to ensure future savings were made or alternately they might modify future plans to take into account "future disobediences". This according to Strotz was an indication that the person was acquiring a "thrifty" nature (Strotz, 1955:165).

Although Strotz could be accused of promoting his own valued judgements, what was of significance in his paper was his treatment of the discount rates relative to time. He declared that a critical aspect of the entire analysis was "that the discount rate applied to a future utility should depend on the time-distance from the present date and not upon the calendar date at which it occurred" (Strotz, 1955:165).

Strotz presented a series of equations in which he assumed each agent had an infinite choice of "alternative time paths of consumption" and where risk and uncertainty were initially

excluded (Strotz, 1955:166). He further assumed that each alternative choice could be ordered transitively and that the ordering could be presented in the following form:

$$\phi\tau = \int_0^T \lambda(t-\tau)\, u\left[C(t),t\right] dt,$$

Where $u[C(t),t]$ is an instantaneous utility function and at each time t a value equivalent $u(t)$ *to* $C(t)$, and where $\lambda(t\text{-}\tau)$ is a discount function where the "value depends notably on the time-distance between a future (or past) date t and present date τ" (Strotz, 1955:167).

Strotz was the first economist to propose an alternative to exponential discounting (Frederick et al, 2002:366). He argued that the weighting of the discount parameter for an agent was dependant on "the time-distance" between two points in time. The preferences of agents would vary depending on the interval of time being contemplated. He also stated that the usual exponential discount function discussed in earlier works, differed from "the true discount function $\lambda(t\text{-}\tau)$", which "over-values the more proximate satisfactions relative to the more distant ones" (Strotz, 1955:177). Figure 3 has been extracted from Strotz's paper and shows clearly his interpretation of the time shape of the "true" discount function, $\lambda(t\text{-}\tau)$. This representation is consistent with the hyperbolic discount functions depicted in later works and to be discussed in the next section.

Figure 1.

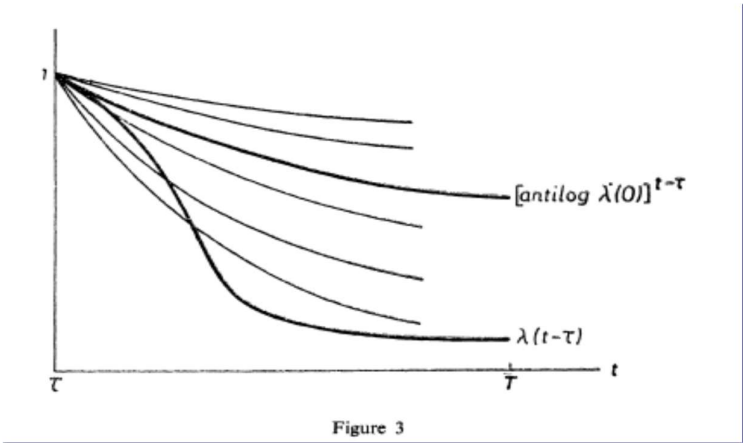

Figure 3

(Strotz, 1955:175)

Strotz suggested that the natural human state is for an agent to possess a discount function in the form $\lambda(t\text{-}\tau)$ which is typical of the spendthrift and it is only through acquired self-constraints and the use of strategies to commit to future savings or the avoidance of plans that are not sustainable, that the agent is able to "substitute the proper log-linear function for the true one[11]" (Strotz., 1955:177).

Referring to Chart 3 we note the space bounded by $[antilog\ \lambda\ (0)]^{t\text{-}\tau}$ and $\lambda(t\text{-}\tau)$, presented in Strotz's graphical representation. This space represents the degree of variation in the agent's discount rate function resulting from the application of their personal perspective on time preferences at each future interval of time. Although Strotz did not refer directly to the psychology of human behaviour in his paper, the approach he adopted attributed the causation in the variance in an agent's intertemporal decisions profile to the influence exerted by their psychological characteristics.

Strotz's paper provided a line of reasoning which identified the time inconsistent nature of the decisions made by agents, which high-lighted their biased tendency towards seeking instant gratification at the expense of long term strategic efficiencies. Indirectly he also acknowledged that the cause of such behaviour was the result of the psychological characteristics which determined the nature of the human condition. The hyperbolic discount models were subsequently developed to provide a more realistic explanation of the intertemporal manifestations of these psychological processes.

1.8 The Hyperbolic Discount Function

There has been an extensive analysis of hyperbolic discount models and the publication of results. It will serve our purpose of developing an understanding of the salient points of this field by focusing initially on a single representative model**.**

"Doing it Now or Later" by O'Donoghue and Rabin expanded on the analysis of Strotz's (1956), Phelps and Pollock (1968), Ainslie (1991, 1992), Lowenstein and Prelec (1992), where the tendency of people to exhibit "present-biased preferences" where further developed

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[11] This is interpreted to mean the natural (true) discount functional form, $\lambda(t\text{-}\tau)$ and that of the "proper log linear function" $[antilog\ \lambda\ (0)]^{t\text{-}\tau}$ as shown in chart 3.

(O'Donoghue and Rabin, 2004:223). An agent when considering the relative benefits of two events occurring at different moments in time, would display a weighted bias towards the earlier of the two. The displayed bias would increase the closer the proximity to the anticipated event. For example if there was an opportunity to take a local holiday in twelve months time or an overseas holiday in eighteen months, a higher proportion of people might be prepared to wait eighteen months. However as the time approaches to take a local holiday, the proportion of people who are still prepared to wait would decrease and furthermore, the rate of decrease would accelerate as the first moment approached. This is in contrast to exponential discount models where the rate of future bias as expressed by the discount rate would be constant.

Strotz categorised the inherent tendency of agents to display this bias as ranging between that of the "spendthrift" where the highest level of time impatience would be observed, to that of the "thrifty" person who is most likely to resist immediate temptation. In the latter case, the thrifty person would recognize the natural propensity for immediate gratification and compensate by either avoiding such behaviour or adopting strategies to commit to thriftiness by employing devices such as saving schemes. O'Donoghue et al. (2004) characterised the spendthrift behaviour as "naivety" and thriftiness as being one of "sophistication" (O'Donoghue et al., 2004: 224).

They proposed a hyperbolic discount model that distinguishes between events where costs are incurred immediately and where rewards are delayed and conversely where rewards are immediate and the costs are delayed. This approach is adopted to unify two different forms of present biased behaviour. The first involves naivety where for example a person may indulge in constant over eating to obtain immediate satisfactions but might experience greater costs due to the prospect of long term health problems. Conversely another person might procrastinate and accumulate unrealised costs which exceed the perceived benefit of delaying the action. For example they may procrastinate at paying a parking fine because of the effort involved in attending to the payment, only to ultimately incur substantial additional costs as a result. The second instance specified is where the person is "sophisticated" and has a degree

of foresight as to their natural propensity[12] to engage in the behaviour of the type outlined in the first example.

O'Donoghue and Rabin's model was based on Phelps and Pollak work on savings models (1968) and the prevalent bias towards under-savings. Using a two parameter discount utility based on an exponential discounting function, the bias for the present is expressed in the following form.

For all t, $U^t\left(u_t, u_{t_+}, \ldots\ldots b\, u_T\right) \equiv \delta' u_t + \beta \cdot \sum^{T} \cdot \delta^{T_\tau}\, \tau$

O'Donoghue and Rabin (2004:227)

Where $0 < \beta,\delta \leq 1$ and δ is the long run time constant exponential discount rate and β is the present bias. If $\beta=1$ then the preference defaults to an exponential relationship but where $\beta<1$, then we have degrees of present bias. In all periods τ, prior to the current period, the bias decreases in each preceding period. To facilitate the modelling process it was assumed that at each point of time there is an independent agent considering the current behavioural maximization options, opposed to separate future selves which are concerned exclusively with future behaviour.

O'Donoghue and Rabin's model categorizes agents into three groupings:

Those with *time consistent* (TC's) preferences. That is their bias for the future is equivalent to $\beta=1$ and they possess standard exponential preferences. *Naïfs* are present biased $\beta<1$ but are naïve in the sense that their ability to rank future time preferences is limited. *Sophisticates* are also present biased $\beta<1$ but they are able to conceptualize future decision frames (O'Donoghue et al. , 2004:229).

O'Donoghue and Rabin (2004) proposed the following definitions of each of the three theoretical behavioural types. *TC's* do not have self-control problems and are perfectly able to perceive in each period if they should engage in an activity to obtain an optimum outcome or to abstain until a superior opportunity occurs in some other future period. *Naïfs* also believe

[12] The term "'natural propensity" is not used by O'Donoghue and Rabin in their paper. They refer to "self-control problems" (2004:224). The distinction is made because it is considered to be a key link to the psychological domain to be later discussed.

that they should only complete the activity in some future optimal period however they differ from TC's because they do not possess the perceptive ability to determine the particular optimal future period in which they should engage. They are more likely to plan a course of action but then change their minds prior to the event. *Sophisticates* also have self control problems but are able to predict their future behaviour and decide to act now only if they believe it is optimal now rather than relying on their future selves. That is they are prepared to act now because they are sceptical about whether they will carry out the act in future (O'Donoghue and Rabin, 2004:23-4). These observations are similar to those outlined by Strotz, when he referred to perceived "future disobediences" of future selves (Strotz, 1955).

The authors also approached the bias observed in an agent's intertemporal decision actions by analysing the welfare effects they encounter. They argue that only a small bias (that is β is close to1) towards acting now opposed to later, can lead to a person incurring a large welfare loss. They assume that *TC's, Naïfs* and *sophisticates* have identical "long run utility" (O'Donoghue et al, 2004:236) and propose that the welfare loss from self-control problems can be measured by the degree of deviation from the TC's long-run utility[13]. In this case the divergence between the total present value of the future welfare-outcome for each of the three types represents the degree of welfare loss over the entire time interval resulting from the bias.

The model implies that the behaviour of naïfs "intuitively and directly reflects their bias for the present" (O'Donoghue et al., 2004:243). The authors claim that the simplicity of this proposition will hold over a wide range of models. For example in savings models where the immediate pay-off for consuming now is preferred by naïfs over saving and delayed consumption, to the benefits derived from increased payoffs as a result of the savings yield, even though these future benefits enhance the prospects for greater future consumption. In this regard naïfs will constantly demonstrate a propensity to under-save in most savings models (O'Donoghue et al., 2004:243). In addition these same characteristics are also observable in addiction models (Becker and Murphy, 1988), where naïfs will yield to some desire today and over indulge seemingly indifferent to the future costs of their actions.

[13] It is not clear in this context what "long run utility" means but it is interpreted here as the utility that is conceptualised to exist at a future point of time where all agents are indifferent to making any further intertemporal decisions.

Sophisticates on the other hand will display behaviour which will contradict their natural inclination towards having present bias tendencies. The level of self-control they impose can be quite severe and sometimes may appear to be obsessive. For example in savings models sophisticates might impose an austerity regime on themselves which might exceed the savings tendencies of even a TC who by definition exhibits an exponential discounted savings schedule. The motivation of such behaviour is the inherent fear of losing control and consequently they adopt personal strategies to overcome their future perceived "weakness".

The authors caution against the over reliance of the assumption of sophisticated behaviour in the models and point out that economists may tend to overly use the concept because it yields results that diverge less from standard neoclassical predictions (O'Donoghue et al, 2004:244). In particular they comment "it is presumed that whatever novel predictions arise assuming sophistication will hold a fortiori assuming naïveté" (O'Donoghue et al, 2004:247). They provide this caution because their model presents scenarios which may be contrary to the implications presented in many standard models. The example provided earlier of the sophisticate who was over zealous with a savings strategy is a case in point.

The authors note that the literature generally tends to portray sophistication as a means to improve behaviour without counter intuitively considering other effects. Referring to Strotz (1956) and Akerlof (1991), they point out that their discussion "reflects the prevalent intuition that sophistication might help to improve behaviour" (O'Donoghue et al 2004:244). O'Donoghue and Robins' model in fact provides for the possibility of divergent outcomes by incorporating the following conditions. When an agent is confronted with present costs, the tendency is to procrastinate but where sophistication is involved, there is a realization that procrastination will also occur in the future and that doing it now will be less costly and thus sophistication is beneficial under these circumstances. However when rewards are immediate, agents will tend to preproperate and again if they are sophisticated they will realize that they will also preproperate in the future, leading to the perception that it is less costly to preproperate now. Under these circumstances it can be implied that when rewards are immediate sophisticates may experience negative consequences (O'Donoghue et al, 2004:245). An example of such behaviour relates to addiction where a sophisticate who would normally be expected to avoid the trap of procrastination and abstain now, might perversely believe that succumbing to temptation in the future is inevitable and therefore may decide to partake now.

1.9 Summary of Part 1

This section has presented an overview of the historical development of intertemporal choice theory. Some of the more significant individual contributions have been discussed together with the increasingly entwined issues of economic research and the study of psychological characteristics of human behaviour. The history also provides a fascinating perspective on how the approach by economists has changed towards the topic over the years. The initial insights of Smith, Rae and Jevons and their observations into the variability of human behaviour were an integral part of their work. Bohm-Bawerk and Irving Fisher laid the foundations for the mathematical expression of intertemporal theory but at the same time their work included insights into human behaviour and the acknowledgment that a perspective on the psychology involved in the decision making process was essential. This psychological focus was largely absent from the body of analysis which followed Samuelson's seminal work on the Discounted Utility model. The time inconsistencies revealed when testing the actual predictions of the exponential discount functions, required further explanation. The development of the hyperbolic discount function following on from the work of Strotz provided renewed insight into the different responses that were revealed by agents in relation to their intertemporal choice decisions. Strotz's model provided a general framework through which the dynamic changes in preferences of agents over time could be expressed. However, his model did not have any major impact on mainstream economics until his work was further developed by Laibson (1997) and Rabin and O'Donoghue (1999), although its significance was certainly acknowledged by Ainslie (1974), Ainslie and Herrnstein (1981), Ainsley and Hhaslam (1992).

As economic theory evolved towards providing a more complete description of how society engages in economic activity, the focus gradually shifted from a philosophical approach to one of providing explanations of how economic structures coalesce in a physical sense. For this reason any complete explanation would ultimately need to confront the process of human behaviour.

Part 2 – Cognitive Psychology and the Economics of Intertemporal Choice

> *Thus every experience contains an indefinite number of unknown factors, not to speak of the fact that every concrete object is always unknown in certain respects, because we cannot know the ultimate nature of matter itself (Carl Jung, 1978:5).*

In the previous section, an historical summary was presented describing how intertemporal choice theory developed into an integral part of contemporary economic analysis. Part of this process involved confronting the reality that all economic decisions made by humans include internal introspection and judgement.

Given the variability of human nature and the inability of early theorists to parameterize those conditions, simplifying assumptions were made concerning certain aspects of human behaviour. Primarily this involved the assumption that agents would conform to an ideal type characterised by a consistent rational behaviour when making economic decisions. In relation to intertemporal choice, it was assumed that agents would maximize utility over time and discount future values using standard discounted cash flow techniques, utilizing exogenously determined rates. This approach excluded the possibility of indeterminate 'irrational' responses which might distort those rates.

Samuelson developed a discounted utility model which incorporated what has been described as the person's pure rate of time preference, effectively establishing a personal discount rate for "an individual whose tastes maintain a certain invariance throughout the time under consideration" (1938:166). The discount rate in effect incorporates the psychological motives of the individual but only as they exist at a discrete point of time (Frederick et al, 2002) and therefore because it is a constant rate, it will be exponential in form (Kirby and Marokovic, 1996). However agents do not always act consistently over time as they often change their previous optimizing selections. These inconsistencies of time relative behaviour, resulted in the development of hyperbolic discounting models (Strotz, 1955; Laibson, 1997; Rabin and O'Donoghue, 1999), which expressed future valuations of utility expressed as functions of multiple discount rates $\{1, \beta.\delta, \beta.\delta^2, \beta.\delta^3\}$. Typically this expression is more usually encountered in the form $\{0 < \beta,\delta \leq 1\}$ where δ is the long run time constant exponential discount rate and β is the present bias. The resultant hyperbolic shape of these future time preferences is attributed to their present bias factors.

In this section the research into the origins of these psychological biases will be investigated. The literature relating to psychological perception characteristics and the behaviour of agents attempting to compensate for their precipitous behaviour and lack of self-control will be examined. This will take the form of a review of the results derived from different areas of research

2.1 Examples of Methodology in Behavioural Economics

To develop a better understanding of the manner in which intertemporal decision theory has evolved, it is useful to understand some of the methodological approaches that developed within the general sphere of behavioural economics.

One of the central figures in the continued development of the methodology is George Lowenstein. One of developments that Lowenstein discusses is an area of research termed Behavioural Decision Making (BDM). (Lowenstein, 2006:26). The fundamental objective of researchers is to analyse a population and to develop a profile of its member's cognitive abilities and the dimensions of those abilities. This symmetry is utilized to analyse behavioural deviations from some construct of a rational ideal type to classify behaviour based on observing the psychological processes associated with judgement and choice (Camerer and Lowenstein, 2004: 9). The analysis of judgement is concerned with how probabilities are processed cognitively and how choices on behaviour are derived from these processes.

A fundamental problem with this approach identified by Lowenstein (2006), relates to the standard economic method of using Bayesian analysis to model probability judgements through statistical sampling and then to update the probabilities as new evidence emerges. This updating process requires a priori input and the separation "between previously judged probabilities and evaluations of the new evidence" (Camerer et al., 2004:9). However this is particularly difficult as aspects of the cognitive process rely on previously acquired information for filtering purposes within the perceptive process, thus "violating this separability" (Camerer et al., 2004:9). In other words the test results might display autocorrelation characteristics between observations over time. Expected subjective utility assumes a separation between the probability assessments of particular states and the anticipated utility derived from those states; however pre-conceived notions and motivations are in "violation of this separation" (Camerer et al, 2004:10).

Lowenstein refers to the development of a new approach which modifies the use of standard Bayesian analysis to incorporate the notion that agents are able to incorrectly specify a set of hypotheses or update memory incorrectly with new information. This approach is termed "quasi-Bayesian" (Camerer et al, 2004:11). This method may reveal the bias of an agent choosing between different alternatives. This was termed a "confirmation bias" (Rabin and Schrag, 1999:38). If a person has a bias between two different automobile brands say BMW and Mercedes, they might never make an encoding[14] error in relation to the Mercedes but occasionally encode incorrectly for the BMW. Similarly a model developed by Mathew Rabin (2002) which focused on "the law of small numbers" infers that "people exaggerate the degree to which small samples resemble the population from which they are drawn" (Rabin, 2002:775).

In the context of intertemporal choice theory a significant body of the research is conducted using experimental economic[15] techniques. Discount rates are elicited in laboratory conditions where subjects are surveyed to determine their responses when receiving a series of hypothetical and real rewards over variable time frames. Fredrick et al (2002) identifies several different sets of techniques used for this purpose the most common being "choice tasks" (Fredrick et al., 2002:386). These involve the subjects choosing between "smaller, more immediate rewards and a larger, more delayed reward" Fredrick et al., (2002:386). This reveals the range of discount rates for the respondent between an immediate and delayed reward. For example, to delay receiving $100 now in preference to receiving the reward in a year's time, the respondent would require $120 which implies a discount rate of at least 20% per annum. By varying the type of reward and delay period, a profile of discount rates may be revealed. However Fredrick et al (2002) pointed out that like all elicitation methods, subtle distinctions could be introduced in the form of cognitive biases created when the original proposition is framed and projected into subsequent iterations of the same decision series. This is termed anchoring and was first identified by Slovic and Lichtenstein (1971) and Tversky and Kahneman (1974).

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[14] The term encoding is used by Lowenstein (2004:110) in context of the cognitive processing of information.

[15] Experimental Economics is a branch of economics which uses controlled experiments to evaluate theories and behavioural assumptions, as well as to test policies and their implementation" (University of Melbourne, 2011)

These types of techniques are of significant importance in understanding and predicting economic behaviour but they do not explain the underlying cognitive conditions that result in the biases reflected in individual judgements. To develop a broader understanding of these cognitive limitations and the implications for the intertemporal decision process, developments in cognitive research will be outlined.

2.2 Origins of Cognitive Psychology in Economics

Herbert Simon and his associates engaged in early foundational research into the effects of cognitive limitations of economic agents. In one of his early publications, "Organizations" (March and Simon, 1958), Simon together with co-author James March, focused on understanding the problem solving processes within an organizational structure and the resultant evolutionary path of adaptation and learning (Egidi and Rizzello, 2003). This initially entailed the development of computational explanations of how agents approached a problem solving task. The assumption of rationality in context of the firm, equates to the maximization of opportunities as its fundamental objective. This approach led to increasingly well defined models of rational behaviour for organizations, involving the requirement of greater computational complexity utilizing sophisticated optimization algorithms (Egidi, 2004:1). However according to the study the solutions enacted by individuals within the organization were subject to the limitations of their cognitive abilities. The reality that needed to be confronted was whether it was reasonable to assume that individuals had the ability to conduct complex decision making processes, of the necessary precision to consistently arrive at perfectly rational outcomes, or alternatively "whether models of rational behaviour should only be interpreted in a normative sense as techniques aiding decision making" (Egidi., 2004:1).

The realization that the further development of the theory of organizational learning was limited by the computational constraints inherent in its members, motivated Simon and his colleagues to develop the hypothesis of bounded rationality. They proposed that the constraint on an individual in effecting a rational decision "was the need to construct the *context* of the decision" (Egidi, 2004:6). The process of framing the mental model, which fundamentally represents applying a derived organizational strategy, is subject to the actor's cognitive constraints. Such limitations represent the bounds to the enactment of the rational solution proposed by the organization.

In "Human Problem Solving" (Newell and Simon, 1972), Simon and Newell analyse the relationship between the human computational process and logical sequences developed in artificial intelligence. They questioned the standard rationalistic assumptions concerning the seemingly perfect human computational process of converting facts through logic into optimum responses. Instead, humans engage in symbolic manipulations of data based on a range of cognitive properties. Simon recognized the restricted ability of humans to perfectly process all of the available data due to cognitive limitations. He proposed that the extent to which they were able to choose rationally amongst all possible alternatives was bounded by these cognitive constraints. In the next section a more complete description of bounded rationality will be presented.

2.3 Bounded Rationality

Peter Earl in the introduction to a series of works on the "The Legacy of Herbert Simon" (Earl, 2001) distinguished between the influences of Simon's theory of bounded rationality had on neoclassical economics opposed to behavioural economics. In neoclassical economics the assumption of rationality and optimization are adjusted to incorporate Simon's theory by allowing rationality to be subject to constraints. Behavioural economics has focused more on the processes that motivates an individual, rather than on instances of behavioural divergence observed in the context of neoclassical market analysis (Earl, P. 2001: xviii-xx).

Simon pointed out that the neoclassical approach does not equate to real life where complexity and information is incomplete and that theories of behaviour deny the rationality assumption and instead focus on the "actual frame of the decision[16] and how, within that frame reason operates" (Simon, 1986:223). He advocated the direct observation of agents either in actual situations or through laboratory analysis to gain an understanding of the agent's beliefs and the processes of "calculation and reasoning" (Simon, 1986:211-212).

Simon wrote, "Everyone agrees that people have reasons for what they do. They have motivations and they use reason (well or badly) to respond to these motivations and reach their goals" 1986:209). According to Simon, an agent's knowledge and ability to compute are limited and inconsistent. However to be meaningful, a theory must be able to "distinguish

[16] Decision Frames refers to the concept where "the psychological principals that govern perception of decision problems and the evaluation of probabilities and outcomes, produce predictable shifts of preference when the same problem is framed in different ways." (Tversky and Kahneman, 1981:453)

between the real world and the actor's perception of it and reasoning about it" (Simon, 1986:211). He suggests that the theory must include not only an explanation of the logical processes but also the agent's subjective understanding of the problem requiring a decision. In neoclassical economics it is assumed a rational agent will reach a decision that will objectively optimize their utility. In cognitive psychology, the agent may be satisfied that they have been rational and have decided optimally, but they hold this belief based on their subjective perceptions of the knowledge that they possess and their individual computational ability.

"Rationality denotes a style of behaviour that is appropriate to the achievement of given goals within limits imposed by given conditions and constraints" Simon, 1972:161). Simon pointed out that there are a vast number of possible decision paths available. To be totally rational, the decision maker would need to be aware of each of these possibilities and perfectly select the optimum decision path but it is not realistic to make this assumption due to the cognitive limitations of the human brain. However it also the case that humans continue to function and make decisions with apparent success although not uniformly (Frantz, 2003).

Simon refers to "satisficing and optimizing" which are "two broad approaches to rational behaviour in situations where complexity and uncertainty make global rationality impossible" (Simon, 1972:170). 'Optimizing' under this circumstance is an approximation resulting from the agent simplifying their view of the real world until its complexity is reduced to a level able to be effectively contemplated. The 'satisficing' approach also seeks to simplify but it retains and utilizes more of the real world information being processed and searches to find a satisfactory solution rather than the approximate best. This method often relies on the adoption of rules to determine a satisfaction level. For example this may involve the inclusion of transaction costs so that the search for a solution is subject to constraints. Simon commented that it is not possible to predict which produces the most optimum result. (Simon, 1972). Thus the agent is constrained by their cognitive limitations which determine the bounds of rationality within which they operate.

Simon demonstrated through experimental processes which were developed to study such behaviour, that agents subject to cognitive capacity constraints involving mental calculations in complex games such as chess, create mental constructs "to manipulate symbols and to create mental models of reality" (Egidi and Rizzello, 2003:12). The awareness that human decision making can be understood only if mental activities are viewed as symbolic

manipulations, resulted in Simon's interest shifting towards a psychological explanation of the cognitive process.

2.4 Cognitive Limitations of Perception

Simon conducted extensive research into human decision processes where complex tasks were involved. This included the observation of chess players and the strategies they adopt to solve problems. He defined the problem confronting chess players as a series of tree alternatives. Because of cognitive limitations, an agent will attempt to simplify the problem by removing from the mental model most of the alternative option branches. This process of simplifying the array of alternatives will result in various degrees of contextual errors. In relation to the chess analogy, the player who defines the problem with the lowest level of contextual errors will win. In a paper by Gobet and Simon (1996) dealing with recognition processing and problem solving engaged in grand-master-level chess, it was shown that a master can remember the positions of up to 25 pieces after only a 5 second scan of the board during the course of a game. Average chess players could only remember less than half of the positions. However if the pieces are placed at random on the board without their positions occurring as a result of the natural progression of previous moves, the additional ability enjoyed by masters disappeared. This appeared to be as a result of the masters recognizing familiar patterns of play and remembering these rather than the positions of individual pieces (Gobet et al., 1996:52). Holding (1985) concluded that the ability to search for future patterns was a far more significant ability than the past pattern recognition skills of players. Gobet and Simon (1996) tested both theories and concluded that chess masters, when subject to time constraints, based the majority of successful moves on recalling recognizable comparative patterns from previous chess games and then making new moves based on those experiences. When not subject to time constraints, players tended to quickly select the most likely move but then spent a considerably longer period checking how the potential move might be impacted by possible future counteraction. It was shown that in the majority of cases the masters did not alter their initial intended move. This supported the view that it was the framing of previously experienced patterns of play which predominately influenced the final decisions (Gobet et el, 1996).

This research tends to support Simon's hypothesis that the cognitive process will contextually frame the problem to be solved based on comparing the perceived observations with patterns recalled from memory that match and then deriving a decision based on that experience

(Frantz, 2003). This is in fact decisions based on heuristics. The contention that an individual whose cognitive abilities successfully "prune" the tree alternatives to reveal the decision components, and more likely to produce the winning strategy, is also supported by the research. The case study was focused specifically at expert learning scenarios where agents that utilize highly evolved skill sets were tested. If we hypothesise that the chess master's level of ability equates to the maximization of rational behaviour, then the natural line for further enquiry might be to understand the nature of these optimizing conditions.

2.5 Dual Stages in the Cognitive Process

In the previous section the process where an agent recalled memory patterns in response to a current perceived event was discussed. This process involved the initial framing of the event in context of the recalled patterns and then a second phase where the initial impressions are reviewed and judgements are made. This two stage process was discussed by Kahneman and Tversky (2000) in a work entitled "Choices Values and Frames" which investigated the psychological principals that govern the creation, perception and evaluation of alternatives in the decision making process. They found that preferences vary substantially according to the way the choice problem are presented or framed. They showed that the preferences are constructed by the individuals in the process of their elicitation.

In his Nobel Prize lecture Daniel Kahneman outlined some important aspects of his work that he conducted with his past colleague Amos Tversky. Kahneman referred to two different generic modes of cognitive functionality. The first system operates as the "intuitive" mode where judgements and decisions are made automatically and instantly. The second system is referred to as the "controlled mode" or the mode in which logical deductive reasoning occurs. This is a much slower process than what occurs in system 1 (Kahneman D., 2002:451). A central concept of this research is that intuitive judgement takes place somewhere between these two systematic processes. Consequently the external observed behaviour of an individual will be determined by these dual cognitive factors.

According to Kahneman, {system 1} is the state in which perceptive functions occur, "The perceptual system and the interactive operations of {system 1} generate impressions of the attributes of objects of perceptions and thought" (2002:451). Also impressions occur spontaneously, cannot be controlled and may be experienced at a non-verbal level. In contrast, {system 2} engages in judgemental processes induced either by impressions

experienced or by deliberate conscious reasoning. In the latter case when contemplative judgements directly match impressions gained, then according to Kahneman, intuitive judgement has occurred.

Another function of system 2 is the monitoring of the quality of mental processes and overt behaviour (Gilbert, 2002; Stanovich and West, 2002). From an anthropomorphic perspective judgements made overtly or otherwise are always accepted by system 2 even if this occurs passively. According to Kahneman and Frederick (2002), the monitoring system is quite lax resulting in a high level of intuitive judgements some of which are ultimately found to be incorrect. Shane Frederick "(personal communication, April 2003", cited in Kahneman, 2002) presented one of a series of puzzles which were designed to monitor cognitive processes. The following is an example and its interpretation.

> A bat and ball cost $1.10 in total. The Ball cost $1.00 more than the ball. How much does the ball cost? Almost everyone reports an initial tendency to answer 10 cents because the sum $1.10 separates naturally into $1 and 10 cents, and 10 cents is about the right magnitude (Kahneman, 2002:451).

The results of tests conducted on students at Princeton and Michigan universities using this particular puzzle showed that between 50 to 56 percent of the subjects gave the wrong answer because they intuitively responded without checking their initial reaction. Kahneman concluded that the test showed that the output of {system1} is lightly monitored by {system 2} as it allowed a high proportion of people to trust quick plausible judgements. In addition he stated that errors "of the same type were significant predictors of relative indifference to delayed rewards (high discount rates) and of cheating" (Kahneman, 2002:452).

In a paper presented by Morewedge and Kahneman (2010) additional research material was presented to provide a more complete explanation of associated memory and in particular its influence on intuitive judgements under conditions previously described under system 1 and system 2. They identified three features of associative activation which result in this influence.

1 Stimulatory events may invoke a "reciprocal activation" (Morewedge et al., 2010:436) of patterns previously encountered resulting in the possibility of confirmatory bias towards a current hypothesis advocated[17]. In a research program into confirmatory

[17] Refer to the prior discussion on Confirmation Bias and encoding errors (Rabin & Schrag, 1999).

biases: “anchoring, hindsight bias, egocentric biases, attribution biases and overconfidence, participants are encouraged to retrieve information that either supports or undermines a focal hypothesis” (Morewedge et al., 2010:436).

2 Despite the advice, no revocation or amendments to their respective positions occurred unless the evidence was incompatible with previously held views and consequently did not invoke a response.

3 Because the domain of individual judgements are associated with one another and overlap, often an attribute of a stimulus will invoke a simultaneous and composite assessment based on the associated memory. For example a job application being assessed by a person who might have attended the same school as the applicant might invoke an involuntary favourable bias because of the deep felt affection the assessor feels towards the old school and in the absence of any additional negative data the applicant might be erroneously favoured. In this case system 1 generated a bias and system 2 failed to confront the associative bias.

4 The fluency of the processing during the determination of judgements has a significant effect on the confidence in the conclusions reached. For example if a group is asked to name 10 overseas capital cities and another group only 5, the first group who might struggle with the final 3 would rate themselves lower at geographical knowledge than the second group who easily named 5 cities.

Morewedge and Kahneman (2010) liken the functions of {systems 1} and {system 2} to that of the operating system and software in a computer environment rather than hardware. System 1 produced “impressions, intuitions and response tendencies that are monitored, sometimes rejected and sometimes modified and made more explicit by the slower and mostly conscious operations of {system 2}” (Morewedge et al., 2010:439). They point to recent research into priming[18] which confirms that there are networks of reciprocal activities linking objectives, ideas, emotional responses and likely signature characteristics of the individual. The priming process activates the associated memory stream into a continuous and “mostly accurate representation of the current state of affairs” (Morewedge et al., 2010:439), that is continually

[18] Priming refers to an increased sensitivity to certain stimuli due to prior experience. Because priming is believed to occur outside of conscious awareness, it is different from memory that relies on the direct retrieval of information (Jacoby, 1983).

evolving, linking the past with probable future events and at all stages at the ready to interact with current activities. The resultant biases emanating from the process of intuitive judgement, produce patterns of "predictable side effects of this highly adaptive mechanism" (Morewedge et al., 2010:439).

Cognitive research has increasingly focused attention on the dualistic nature of the motivational origins of an individual's behavioural pattern. The cognitive activity between the first processes where impressions perceived following some stimulatory input and the subsequent methodical judgemental review of these native impressions creates an interface. This interface at any point of time represents the frames in which reality is perceived and acted upon by the individual. The discussion on cognitive science has included references to tests which have been performed to identify the relevant function and purpose of these dual systems. The issue of the reviewing function of {system 2}, that filters the perceptive output of long term memory, thus determining the quality of the decisions that subsequently are to be converted into action, creates a subjective space in which to judge degrees of rationality. How accurately people reprocess their historical experiences in a current context will often determine how successful they are in adapting to current circumstances and maximizing their economic opportunities.

In the case of our investigations into the nature of intertemporal decisions clearly how {system 2} operates in moderating behavioural responses emanating from {system 1} will have a bearing on the resultant intertemporal profile that is revealed by the subject agent. The degree to which the immediate perceptions are filtered, evaluated and judged will impact on how the decisions are ordered in time relative to the maximizing of benefits[19]. A normative view of the intertemporal behavioural profile of an agent from a cognitive perspective such as outlined by Kahneman (2002), could be when the judgemental process is optimum, the agent would display exponential discount characteristics in relation to such ordering. In a non-optimal world the alternative view would be that such ordering is imperfect and that the biases introduced from the {system 1} intuitive processes, may produce a time shape profile more hyperbolic in nature. That is, the agent might be more inclined to engage in behaviour which could be viewed as being impulsive in context of timing when compared against an

[19]The term maximizing of benefits is used in context of the neoclassical assumption of rational behavior.

alternative involving a rational judgement not subject to a time immediacy bias (Kahneman, 2002:452).

For this hypothesis to be tested it is necessary to review the research that is being conducted within neuronal and psychological sciences, into which neurological sectors of the brain are likely to be associated with the decision processes. In the next section, the research into the determinants of economic decisions will be discussed using experiments to observe intertemporal behaviour under controlled conditions.

2.6 Experimental Research in Support of Hyperbolic Discounting

Hyperbolic Discounting theory provides the analytical tool to explain the effect of temporary preferences not effectively covered by conventional exponential discounting models. (Ainslie and Haslam, 1992). The authors point out that hyperbolic functions are common where physical quantities are involved and delays are not involved. They refer to the "Weber-Fechner law" which states that "a change in a physical stimulus is perceived not proportionately to its absolute amount but as a ratio to the prior amount" (Ainslie et al, 1992:71). Applying this law to perceptions of delay as expressed through a discounting model suggests for example "that a delay from tomorrow to the day after tomorrow should be spontaneously perceived as 30 times as great as the delay from next month to next month plus a day" (Ainslie et al., 1992:72).

However, Ainsley and Haslam point out that there is a conceptual error in this approach because when making the transition from understanding relative changes in a physical space to those involving perceptions of time, the relationship does not hold. They provide the following comparison.

Adjustments of perception in physical space generally occur without anomaly. A child soon learns that the height of a light pole in the foreground is the same as another in the distance. The mind learns to compensate for the initial visual anomaly. Similarly the impression of the size of a distant object does not change as one is approaching the object. The cognitive process self calibrates the changing image and provides a consistent feedback of the spatial changes that are occurring. Where spatial relativity is more complex we are able to apply systems of measurement based on objective standards (Ainsley et al, 1992:72). However

when evaluating goods at different future points in time, significant valuation inconsistencies become evident despite the ability to calibrate time into discrete intervals. Unlike relative differences in physical space, people seem unable to naturally compensate for time differences when evaluating utility from future goods. Ainslie and Haslam point to this anomaly as being central to the issue of temporary preferences and the inconsistency in the revealed bias presented within a series of hyperbolic discount curves for a single agent (Ainslie et al 1992:73).

Temporary preferences are identified by Ainslie and Haslam as having a significant influence on the variance in the shape of hyperbolic curves compared to those derived from exponential modelling.

They further suggest that agents are more likely to prefer to adopt a future behaviour which could be described as rational. However as alternative opportunities arise as they progress through time, their commitment may suddenly lapse and they may change their preference to a present alternative. In retrospect they might regret their transgression and reflect on the resilience of their own will power but such reflection does not necessarily change their propensity for avoiding future deviations.

One of the early researchers into intertemporal behaviour under experimental conditions was George Ainslie. His classic work involving pigeons provided some compelling evidence for the existence of hyperbolic discounting tendencies in individuals as well as the adoption of commitment strategies to counter a perceived lack of self control.

This research shows that ‘pigeons will choose a shorter, earlier access to grain over a later, larger one when the shorter one is immediate and not when it’s delayed” (Ainslie, 2001:30). The following chart in Figure 2 was extracted from a paper by Ainslie and Herrnstein (1981) showing changes in preferences relative to time.

Figure 2.

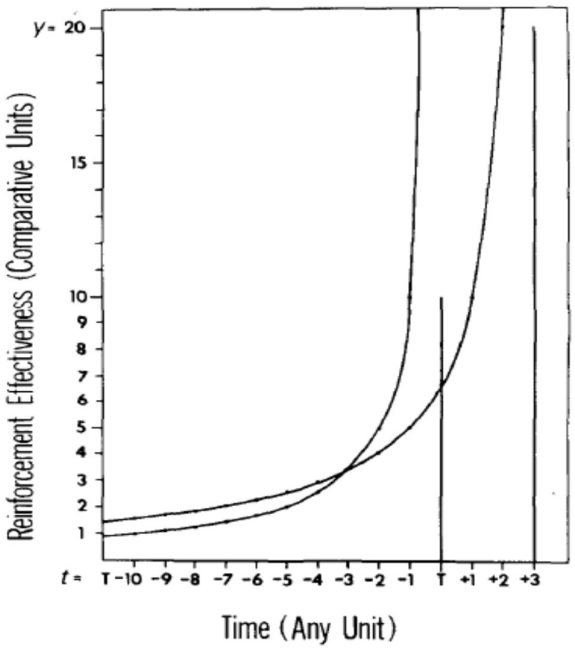


Figure 1. Hyperbolic discount curves showing the effectiveness of two hypothetical reinforcements as a function of delay: the effectiveness, at any given moment on the time axis, t, of a reinforcement occurring at time T vs. a reinforcement twice as large occurring at time T + 3. Left curve shows $y = 10/(T - t)$; right curve, $y = 20/[(T + 3) - t]$.

The results show the responses of the subjects when given pairs of reinforces (food), varying in amount and delay. As the reward T in time t grows closer preferences may suddenly shift from the more remote and larger reinforcer to the smaller but earlier one.

This sudden shift in preference is termed "preference reversal". In this case the reversal occurs at t = -3.

This research tends to confirm that the pigeons display intertemporal choice characterises in respect to choosing an immediate reward compared to a later one. The subjects reversed their preferences depending on how they reacted to the changes in the experimental conditions.

Another aspect of the research showed that "some of them will actually peck a coloured key in advance to prevent themselves from later getting offered a differently coloured key that produces the smaller reward" (Ainslie et al, 2001:30). In effect it was shown that some

pigeons learned how to employ the use of a commitment device (the choice of a particular key sequence), to avoid the impulse of taking a smaller reward sooner (Ainslie, 1974)

Although this form of research provides some dramatic insights into the nature of intertemporal choice and commitment strategies, it is limited by its ability to separate responses that are due to cognitive limitations opposed to the possibility of the existence of other factors that may influence behaviour.

In the previous section we examined the behavioural responses emanating from cognitive research into the process where a person's spontaneous perception within their current environment (the intuitive) is filtered and interpreted through contemplation (the judgement). However when we conceptualize intertemporal choice theory and the time bias reflected in the hyperbolic discounting representations, Kahneman's (2002) theory of the intuitive initial reactions {System 1} resulting from an input stimuli, it provides a plausible explanation of the origins of a time bias In addition, a lightly monitoring {System 2} either allows the reaction to manifest in the form of the time bias or is insufficient to invoke motivation through 'will power' to counter the bias. Certainly in the case of Ainslie's pigeons, some of them were able to overcome their initial desires for gratification {System 1} and presumably engage in a strategy {System 2} to forestall their immediate desires. In the latter case their adoption of a strategy is consistent with the theory of commitment devices.

To further provide empirical support for the dual system hypothesis some of the research into the psychological and neurological functioning of the brain will be discussed.

2.7 Neurological Research in Support of Hyperbolic Discounting

Intertemporal choices result from an inner evaluation by an agent ranking costs against benefits over time (Wittmann and Paulus, 2009). Often this will involve some form of inner conflict between immediate rewards and those that may be delayed. Wittmann and Paulus (2009), explore the scope of the research into the neuronal and psychological determinants of intertemporal choice under test conditions. The research reviewed includes the use of functional magnetic resonance imaging technology (fMRI), on subjects where economic decisions involving intertemporal judgements were involved. Distinctive brain regions

involving “the neural correlates of intertemporal decisions in humans” (Wittmann et al., 2009:71), have been the subject of these research programs.

These distinct brain regions have been observed to be more active in subjects who “are more present orientated” (Wittmann et al., 2009:71). That is they tend to choose immediate available options rather than applying the will power to practice patience and self control. This duality of the decision process is a reoccurring theme within intertemporal research. In this case the duality relates to whether there are two separate competing sections of the brain, one responsible for impulsive behaviour and the other self-control.

Wittmann (2009) discusses the challenging research that is occurring into mapping the structure of neural connections that are involved with intertemporal decisions. This includes understanding the linkages between neuronal mechanisms and the way individuals perceive time under circumstances where “Temporal intervals lasting only seconds or spanning a lifetime are judged according to their duration” (Wittmann, 2009:1955).

One of the complexities in quantifying temporal intervals is that unlike other human sensory systems which monitor stimulatory inputs such as sight, sound, smell and touch, individuals “are not equipped with a sensory organ for the passage of time” (Wittmann, 2009:1955). This anomaly was discussed by Ainslie and Haslam (1992) where the example of a person approaching and observing a distant object, automatically adjusts for the change in perceived size as it becomes nearer. When people think of or verbalize time concepts, they resort to “linguistic structures” (Wittmann, 2009:1955). For example ‘it seemed like I had to wait ages until pay day’ or ‘time flew buy quickly because I was busy’. We may verbalize other occurrences such as being at a particular point in space which may be verified by empirical data; however this is not the case with time perception. “Perceived time, thereafter, represents the mental status of the beholder” (Wittmann, 2009:1955), which in functional form would be expressed as $t = f(\text{self})$. Time is a function of self (Wittmann, 2009:1955).

Zakay and Block (2004) refer to two different influences on time estimation, one involving perspective time and the other retrospective time. In the first instance the observer judges the duration of time that is currently occurring. In the other instance the observer estimates the amount of elapsed time that has occurred in the past but only as being contemplated in the present. Models involving perspective time include an assumed internal clock which accumulates discrete time units. Zakay and Block, (1997) propose that these time units are

only considered when the observer directly contemplates time within a current cognitive processing session. This requires current cognitive resources to be shared between prospective time attention and all the other non-temporal activities. Therefore according to Wittmann (2009), as well as the process of experiencing the inner clocked time, prospective time perception involves other cognitive processes such as "working memory, long-term memory, attention and decisions" (Wittmann, 2009:1956). The episodes of time attention are recorded in working memory and when a decision is being made relative to timing, a comparison is made against stored time representations held in long term memory. The resultant experience then may be verbalized in terms of the discrete time units following this conceptualization (Wittmann, 2009:1956). In the case of retrospective time, the time duration that was experienced has to be evaluated and judged before it can be conceptualized. The validity of this conceptualization is dependent on the quantity of relevant processed and stored long term memory from which the estimate of the "duration has to be re-constructed" (Wittmann, 2009:1956). Bailey and Areni (2006) suggest that the greater the frequency of different experiences within a particular time span that have to be stored and then retrieved the greater the subjective impressions of time duration. This leads to the conclusion that routine events "when compared to novel activity leads to the perception of shorter time intervals" (Wittmann, 2009:1957).

In the paper, "Time Discounting for Primary Rewards", McClure, Ericsson, Laibson, Loewenstein and Cohen present experimental results to support the existence of hyperbolic discounting (2007). These experiments also utilizing fMRI techniques focused on testing intertemporal choice using as the primary rewards juice and water instead of monetary based objects as used in previous tests. The advantage of this method was that the responses received under conditions where brain activity is separately controlled, facilitated analysis on both the desire for the object (to consume the cool drink) and the consumption of the reward (the gratification). This primacy according to the authors was designed to overcome some of the prior objections (Read and Roelofsma, 2003) to time discounting studies in people (Ainslie and Monterosso, 2002), which did not include control separation. The expected outcome for the experiment was for the subjects to display the same intertemporal patterns as found in previous tests reported by (McClure, Laibson, Loewenstein and Cohen, 2004).

McClure et al (2007) presented the two system relationship in the following functional form.

Using a quasi-hyperbolic discount function for a present value of consumption streams (c_1, c_2 ..) taking the form.

$$V_t = u(c_t) + \beta \cdot \sum_{t=1}^{\infty} \delta^t u(c_t + r)$$

Where u is the utility function and discount parameters β and δ are bounded between 0 and 1 (McClure et al., 2007:5796). They then present the function as a multiplicative scaled transformation of V decomposed into two separate processes.

$$W_t = \left(\frac{1}{\beta} - 1\right) u(Ct) + \sum_{r=0}^{\infty} \delta^r u\left(Ct + r\right)$$

---------- ----------

β *system* δ *system*

The {δ system} exhibits the exponential discounting factor and {β system} represents the extra weight for immediate rewards (McClure et al., 2007:5796).

The authors expected those impatient traits represented by β *system* to affect the "limbic reward areas".[20] They also point to research which shows that a greater level of activity in those areas are indicative of people who display reactions concerning gains and loss of money and favour immediate rewards (McClure et al., 2007:5796). They also expected the δ *system* to be associated with the prefrontal and parietal cortex activations. The results of their tests indicated that thirsty individuals, subject to delays of up to 2 minutes discount rewards substantially. They measured that the subjects discount rewards by up to 50% rather than wait an average of 5 minutes (McClure et al, 2007:5802). This was consistent with the previous monetary based study (McClure et al, 2004) where gift vouchers were used. This outcome tends to support the β *system* hypothesis.

Although the methodology was different to that used in earlier tests, the outcome identifies a consistent array of brain areas that are involved in discounting. Activity in the (limbic reward) β system decays rapidly as opportunities for reward are delayed. The (frontal/parietal) δ system is much less sensitive to the timing of available rewards (McClure et al., 2007: 5802).

[20] The authors refer to the limbic reward area as representing the mesolimbic dopamine system and associated structures.

The authors conclude the study supports their proposal for a discount model that has two separate constant exponential discount functions, each of which is linked to separate neural systems (limbic {β} and frontal/parietal{δ}), the aggregate of which forms the quasi-hyperbolic model. Refer to Figure 3.

A re-occurring theme within the intertemporal choice literature is the many instances of theories involving two opposing forces, particularly within explanations involving the cognitive process. In this paper we have discussed Smith's references to 'prodigality' and 'parsimony'; Fisher's description of a 'personal equation' included the elements habit' and 'foresight'; Stotz's dynamic utility model incorporating 'spend thriftiness' and 'thrift'. O'Donoghue and Rabin refer to 'naifs' and 'sophisicates'; hyperbolic discounting functions generally, β (the present bias) δ (exponential rationality) and Kahneman and Tversky deduct 'System 1' and' System 2'. Finally in the multidiscipline approach of neuroeconomics, these conflicting influences are pinpointed to the limbic {β} and frontal/parietal {δ} areas of the brain. Neuroeconomic theories that describe these conflicting intertemporal processes are referred to as dual brain models (Bernheim & Rangel, 2004; Gul & Pesendorfer, 2001).

Schull and Zaloom (2011) discus disagreements that exist between economists who advance the competing neural system models and the neurologists who tend to regard the brain as a single organism. In an interview with the authors, David Laibson (2005: pers. comm.) commented, "Neuroscientists don't like the word 'limbic system' – it's too crude a term for all the different sub-organs". He went on to explain "I talk the way economists want to talk, two brains. It's just an approximation of the world, a good way of organizing the data"

Scholl and Zaloumi (2011) point out that biological science prefers models that:

> ..can accommodate the complex morphological and functioning constraints on the brain while economists strong theoretical tradition leads them to favour a 'dual system model' that can reduce the brain and its functions into mathematically manageable formulae (Scholl et al., 2011: 517).

However despite these framing differences, there would seem to be a strong collaboration between the disciplines which continues to attract interest.

2.8 Self Control and Commitment Devices

This brief overview of the neurological mechanisms supports previous observations that intertemporal choice behaviour is controlled by cognitive processes. The research provides evidence supporting the view that there is a natural tendency for agents to be subject to the immediacy of {System 1; β; *limbic*}' and that through introspection and the motivational influence of {System 2; δ; *frontal/parietal*} they may exert self control on their future behaviours. McClure et al, 2007: 5796) referred to the experiments utilizing the fMRI techniques, which confirmed that people "with greater activation in these limbic reward regions" (McClure et al., 2007: 5796) demonstrated a greater tendency towards immediacy.

The question remains what causes some people to be able to proceed through life consistently displaying the capacity to make choices which demonstrate foresight, whilst others struggle to organise their affairs, seemingly captured by the desire for immediacy. The concept of self-control is synonymous with that of will power. Ainslie, in his book "Breakdown of Will", discusses Aristotle's views on the subject. Aristotle referred to the term "akrasia" to define as "a weakness of will" (2001). Willpower[21] may be characterised as "the faculty by which we improve some over-riding value of ours on the array of pressures and temptations that seem intrinsic" (Ainslie, 2001:3). One manifestation of willpower is the use of commitment devices to ensure that that the improvement of the "over-riding value" is not disturbed by "akrasia". The purpose of such a device is to forestall the likelihood that the agent will succumb to temptation. Commitment devices take a variety of forms. For example they may involve making a commitment that will result in a 'loss of face' socially if the individual deviates from a plan. If a person joins a weight watchers club they are more likely to stick to the plan rather than be shown to fail should they deviate. Many people enter into long term financial commitments such as holding a mortgage over an asset where they are required to make regular payments to reduce the loan. This may encourage saving through the forced reduction of the mortgage rather than the tendency to splurge.

[21] Ainslie refers to the considerable literature that exists about 'willpower' up to the time of the Great War and how the prevailing positive view up until that point of time collectively changed to one of abhorrence. The realization that men of will in pursuit of honour and gain presided over the huge carnage and destruction of society, resulted in the ideal of willpower changing to one of negativity.

Laibson (1997) in a paper "Golden Eggs and Hyperbolic Discounting" discussed how hyperbolic discount functions "induce dynamically inconsistent preferences" (Laibson, 1997:443). He suggests that many people regard self-control as a virtue and that the realization they are subject to a natural tendency to weaken; motivates them to counter this prospect. As discussed many people employ commitment devices to help combat these inherent tendencies.

The chart presented in Figure 3 (Laibson, 1997) compares hyperbolic and exponential discount functions. The exponential function is characterised by a uniform rate of discount applied evenly across a future time frame. It implies that there is no intertemporal bias involved by an agent when determining a future value. It uniformly presents the current value of the subject at each increment of time into the future. In contrast the hyperbolic discount function shown in Figure 3 in effect reflects the existence of at least two rates of discount, the first an immediate initial high rate and then a much lower rate that applies across the balance of the time frame. Liabson suggests that this disparity in rates causes a conflict between current and future preferences. For example we have a choice to be made at current time t or at future alternative times, $t + 1$ or $t + 2$. The nature of the hyperbolic discounting is such that at the current time t the value of utility is subject to the high bias discount factor β. However the discount factor at future period's $t + 1$ and $t + 2$ revert to the exponential discount rate δ.

Figure 3

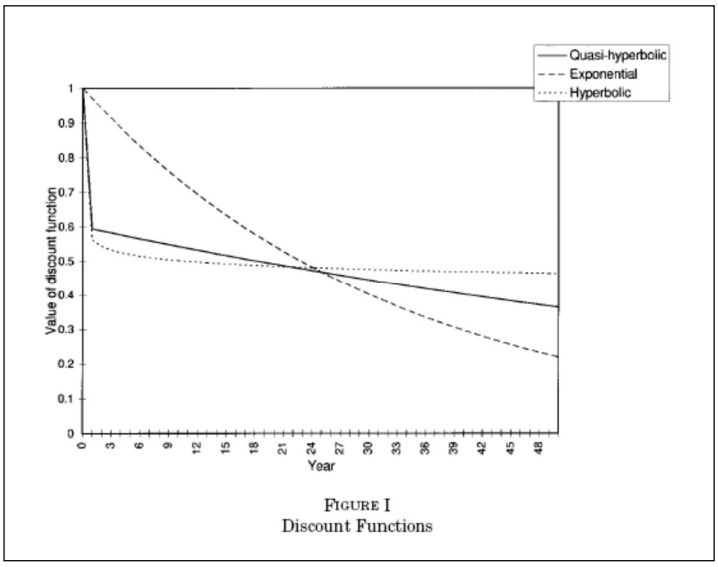


FIGURE I
Discount Functions

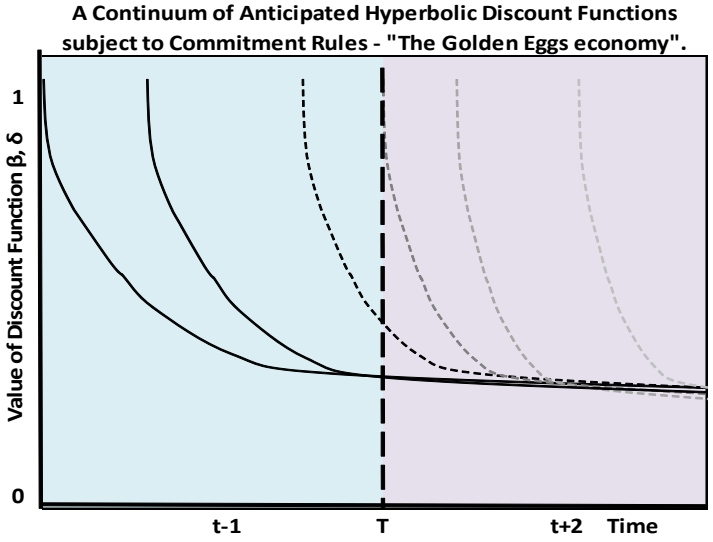
(Laibson, 1997)

In this case the agent without restraint would succumb to the bias in present time t but would be indifferent (zero bias) between $t + 1$ and $t + 2$. The former condition is referred to as a preference reversal and was previously described in Ainslie's research into the intertemporal behaviour of pigeons (Ainslie, 1974; Ainslie and Herrnstein, 1981), but has also been observed in humans (Kirby and Herrnstein, 1995; Thaler, 1981; Lowenstein and Prelec, 1992). Such behaviour has been described as "instant gratification" but as pointed out by Laibson (2005), people do not normally act impatiently towards a future plan such as going on a diet next week but only "splurge today" in the present.

The effect of a commitment device is to inhibit the ability of an agent to choose in the present and thus succumb to their bias and instead to delay their ability to make the choice until such time as the bias dissipates. This effect is well demonstrated in Ainslie and Herrnstein's (1981) chart shown in figure 2.

The example in Figure 4 depicts how an agent employs a commitment device to forestall their impatience until such time as their long term exponential rate is simulated. Liabson refers to this process in the following terms, "the decision maker foresees these conflicts and uses a stylized commitment technology to partially limit the options available in the future" (Liabson, 1997:446). The commitment device forestalls the person's ability to suddenly reverse preferences and delays the opportunity to succumb until the bias decays over time.

Figure 4.



If the commitment device was in the form of a contract for example a mortgage over an illiquid asset, the agent commits a portion of a current and expected income stream at present time T to fulfil her commitment under the contract. During time interval t+n, the level of disposable income is restricted by the contractual obligation. Laibson's (1997) paper will be reviewed in more detail in conjunction with the discussion presented in Case 2, study section 3.3.

It is noted that the apparent rationality of commitments is predicated on a continuation of existing preferences for risk and anticipation of future income streams. In reality external shocks for example such as a major credit rating downgrade might suddenly cease this continuum resulting in a re-ordering of preferences. This prospect highlights the subjective nature of the ordering of future preferences.

2.9 Summary of Part 2

In Part 1 the evolution of intertemporal choice theory was traced from its early interpretation by the classical economists through to the hyperbolic discount models developed by behavioural economists. During the later stages of this development there existed a separate area of psychological and cognitive research into intertemporal behaviour. The results that were produced from this field of research enabled economists to develop a more realistic description of intertemporal behaviour and also provide proof as to the validity of the hyperbolic models they had developed.

Herbert Simon (1958) modelled the maximization of organizational conditions in the firm but concluded that the computational requirements would be beyond the cognitive capacity of its agents to implement. This resulted in the development of the theory of Bounded Rationality.

Early linkages between the cognitive process and intertemporal behaviour were established by Ainslie (1974) through the observation of pigeons under experimental conditions. He was able to establish that discounting of future events was hyperbolic with impatience imposing a bias towards immediacy. He was able to show the process of preference reversal occurred when a future event became relatively imminent. His studies also provided some evidence to support the theory that some subjects would engage in commitment behaviour to forestall the likelihood of reversing their preferences.

Studies into cognitive behaviour developed a view of how people processed, learned and stored memories and recalled those memories through pattern recognition. The accuracy of this process was constrained by the cognitive capacity of the person and ultimately determined the quality of decisions they would make. Responses were based on the contextual framing of perceived current events following the recall of a matching memory.

Kahneman and Tversky (2000) theorized that there were two fundamental systems processing this cognitive traffic. {System 1} produced intuitive responses, based on the spontaneous recall of memory and {System 2} contemplated, evaluated and judged those intuitive responses for adequacy prior to committing to a decision. They hypothesised, that the respective dominance of these two processes contributed to the likely decisional profile of a subject.

Laibson (1997) became instrumental in developing a model that connected intertemporal choice behaviour with potentially significant macroeconomic outcomes. His explanation of how agents cope with their self defeating behaviour through the use of commitment devices in financial markets drew attention to possible adverse effects on aggregate outcomes where the functionality of the commitment device was undermined by the behaviour of financial intermediaries.

Finally the subjective nature of the expectations for commitment strategies was discussed. Expectations for particular outcomes can only be based on probabilities. Preferences may be re-ordered where sudden unanticipated changes in the intertemporal environment suddenly occur.

Part 3 – Discussion

> *But something clicked inside my head the very first time I played the pokies. It was the start of years of addiction, years in which I ### away close to $100,000 and destroyed the trust of everyone I knew. I was a poker machine addict, and no matter my intentions, I simply could not stop playing. Suicide became an option I seriously contemplated, and it took discovery, exposure and the loss of everything I had to finally force my hand and give me the ability to step away (Tom Cummings, 2011). h*ttp://www.abc.net.au/unleashed/3052574.html

3.1 Significance of Intertemporal Choice Theory in Mainstream Economics

In every aspect of daily life people need to make decisions that require them to evaluate intertemporal choices. These might be personal decisions on how individuals allocate time and resources or they could be large corporate or governmental decisions which may have far reaching economic and social implications. Every time a central bank governor speaks in guarded tones on monetary policy, intertemporal ripples flow through the economy impacting on certainty and risk expectations. Allen Greenspan turned this into an art form. However there is only limited treatment of the subject in the mainstream economic literature. Elementary micro and macro textbooks generally only deal briefly with the subject, usually confining the discussions to intertemporal budget constraints and indifference curves. There usually is no discussion on hyperbolic discounting, cognitive psychology or the role that commitment devices play in the economy.

To draw attention to this inadequacy, I will provide two cases of how matters involving the intertemporal choices have major economic and social ramifications. Both examples involve the use of commitment devices one regulated the other self administered.

3.2 Case 1

The use of regulated commitment devices, to forestall habitual personal over expenditure on poker machine gambling in Australia.

The opening quote to this section is of Cumming's experience with addiction involving gaming machines. His gambling addiction is not unique with approximately 290,000 of Australians categorized as problem gamblers. The Productivity Commission estimates that 34% of revenue from gaming machines in Australia is derived from problem gamblers with average expenditure totalling $12,000 per user per annum compared to $650 per annum for other gamblers (Productivity Commission, 1999).

The gaming industry claims that industry revenue in Australia is $10 billion per annum and employs 140,000 people. According to a report produced by the Centre for International Economics (2009) the loss of this sector and the consequent reallocation of labour and capital that would occur following its closure, would result in an annual loss in GDP of 1.3 billion per. The social cost to the addicts, their families and the community generally has not been included in this report nor the $20 million being spent by the clubs industry on running the anti pre-commitment campaign to forestall the legislation.

The stakes are clearly high for the individual, industry and the economy. Currently legislation is about to go before the Commonwealth Parliament to further regulate the gaming machine industry. Venues will have to adopt new technology to cause users to register and pre-commit prior to each gambling session, the maximum amount they are prepared to lose. The Productivity Commission Report into Gambling (2010, Sect. 7) recommends this action on the basis that "Measures that allow gamblers to determine limits on their playing – known as 'pre-commitment' – provide a key mechanism for improving informed consent." (ibid, 2010:10.1). Interestingly within the entire report or in articles associated with this debate, there is very little reference to the research carried out within the intertemporal choice literature.

The Productivity Commissions Report could have included a non-technical explanation of how some people are disposed to succumbing to immediacy without the personal ability to objectively judge the consequences of their actions. Even though they might start a gambling session with a preference to cease when the losses reach a certain level, they experience a continuous series of preference reversals due to the prospect of the reinforcement obtained from pressing the button for the next spin. They are unable to cognitively construct the necessary personnel commitment device to break the cycle of their behaviour.

Bernhem and Rangel (2004) presented a paper dealing with addiction and made the following observations. Addict's usage is frequently due to mistaken choice selection given a set of preferences. The experience developed by the continued use of the addictive substance or activity is often perpetuated by triggering as a result of events or cues encountered within the environment frequented by the addict. Addicts realize their susceptibility to cue-triggered mistakes and may be able to manage the process by avoiding the cue-triggering processes where commitment devices are available. In particular the authors cited the use of pre-commitment strategies as a way of breaking cue-triggered cycles.

The recognition in the public policy area that these people are suffering from a cognitive aberration would reduce the social stigma and promote more considerate support for introducing a regulated commitment device in the form of the pre-commitment limit and reduce the economic and social damage.

3.3 Case 2

Implications of David Laibson's "Golden Eggs and Hyperbolic Discounting" for Economic Policy

David Laibson (1997) drew attention to how financial innovation potentially negates the functionality of commitment devices involving financial contracts. He pointed out that contracts which require a person to commit a portion of their current liquid assets derived from income towards a savings device[22], is predicated on the assumption that the accumulation of value remains illiquid. He referred to the growth in the financial innovation industry where lines of credit can be made available based on the current valuation of the illiquid asset, potentially challenging the individual's ability to moderate their current bias. His model suggested "that financial innovation may have caused the ongoing decline in the U.S. savings rates, since financial innovation increases liquidity and eliminates implicit commitment opportunities" (Laibson, 1997).

He also presented a welfare analysis of financial innovation where he measured welfare loss by estimating the value of a "minimum one-time payment-paid to a representative consumer - which would induce the representative consumer to switch from an infinite horizon golden eggs economy, to an infinite horizon instantaneous credit economy" (Laibson, 1997:465). He expressed the level of payment as a ratio of output (determined by the level of capital preserved in prior periods), individualised by the personal value of the hyperbolic discount bias factor $\beta > 0 < 1$. He noted that where $\beta=1$ no welfare loss occurred but this increased rapidly as β approached 1. Effectively in all cases welfare loss occurs as a result of switching expectations from a continuum involving accumulation via commitment, to one where the continuum is characterised by freely available credit.

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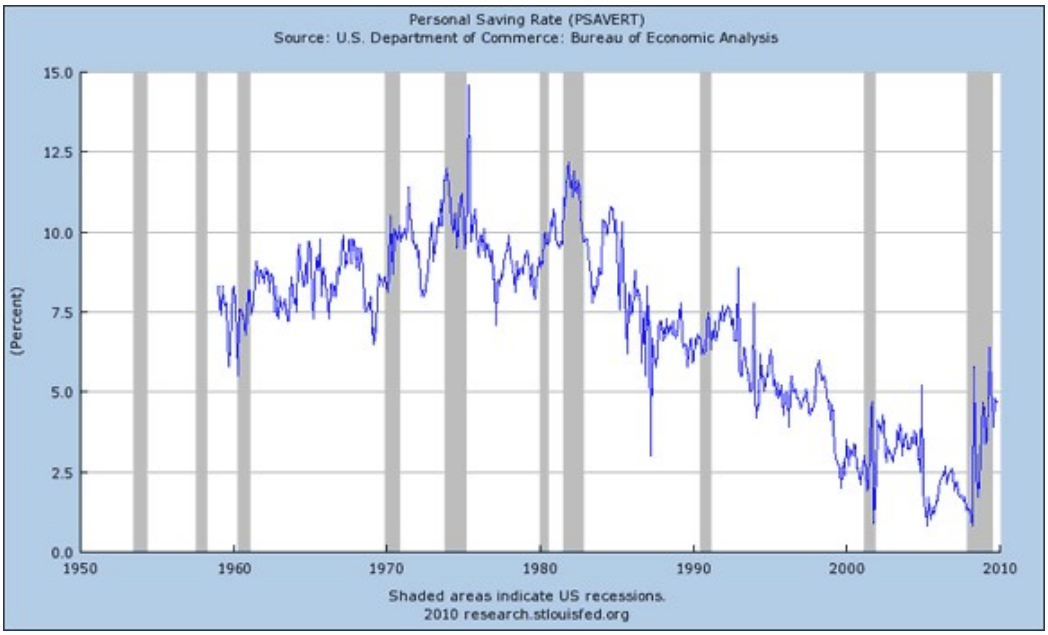
[22] The Golden Egg Savings Funds are typically pension funds. Citizens commit income to these funds for the purpose of their retirement. In the context of Laibson's paper they also include mortgages or any other financial device where a person is committed to converting liquid to illiquid assets from current income.

Laibson (1997) discussed the implications for current consumption and the consequences of saving to support the needs of our future selves. There exists a potential conflict of interest between our current selves and our future selves. This is a subjective conflict as we have no way of objectively representing our future selves' opinion. It is purely conjectural. However what is of significance is the actual behaviour that may be observed related to savings decisions. It is noted that in 1994 US household sector domestic assets totalled $28.5 trillion of which two thirds were illiquid (Laibson, 1997). We also note the changes in the US savings rate since that time.

Figure 5.



(Martin, N. 2010)

The decline since the early 1980's corresponds with the long period of economic growth that occurred over this period. In recessions, savings rates increase as expectations change and consequently income and consumption patterns are disrupted.

Theories such as the Life Cycle Hypothesis (LCH) focus on the relationship between income, savings and consumption over the life of an individual and the consequent aggregate effect on economies. In a paper by Modigliani (1986) the development of associated theories are discussed. He referred to the Keynesian consumption function contained in The General Theory, which he stated postulates that current consumption is due entirely to the level of disposable income currently received by individuals. Modigliani argues that such a notion

was an over simplification not supported by long term empirical data. The alternative view expressed in the LCH was "that the savings rate was explained not by the absolute income of the family but rather by its income relative to overall mean income" (Modigliani, 1986:298). This implies that a consumer at any age depends on whole of life resources and will consume at a stable rate consistent with the "anticipated average life consumption" (Modigliani, 1986). The LCH theory therefore would seem to be dependent not only on past consumption patterns but also the expectations as to the stability of future income levels and the anticipated savings rate necessary to effect the smoothing of future consumption. As a consequence the reliance on the long term institutional stability of savings systems would seem to be pivotal to the application of the hypothesis.

Keynes' hypothesis was developed from the perspective of the Great Depression. LCH and associated models emerged during the long period of post war prosperity. The focus of economic study to some degree is influenced by emergence of contemporary events.

What is of interest is the connection between Laibson's observations from the perspective of 1997 concerning the impacts of financial innovation on savings and now how 'our future selves' post Global Financial Crisis, now interpret the systemic failure of the financial system. Our current perception is that it now seems inconceivable how the weak regulatory regime that prevailed could have been allowed to operate over that extensive period of time. The regulation of financial markets is now the centre of attention once again. That is due entirely to our perception of the past. The expression of ideas and concepts are conceived in terms of our current and past experiences. Our frame of experience is now different and so is current economic policy.

In retrospect we are able to observe that Laibson's hypothesis seems robust particularly from the perspective of the events of 2007, but clearly his observations and those aware of the implications of negative savings rates had little influence with those that framed regulatory policy in 1997. Public policy in the US at that time was light on regulation. Financial innovation together with the application of marketing techniques to re-order consumer preferences towards consumerism, effectively simulated Laibson's stylised 'infinite horizon instantaneous credit economy'.

Based on our retrospective experiences since the Global Financial Crisis, the inadequacy of international prudential regulations is now apparent. Financial regulators should pay greater

attention towards intertemporal variability in individuals. The unintended consequences that result when instruments of financial innovation undermine the traditional role of the commitment device in managing personal savings should be carefully considered by regulators.

3.4 Conclusion

Intertemporal choice theory appears to have evolved along two planes. The first has developed within the strictures of neoclassical economics where the assumption of perfect utility maximization is relaxed to allow the actor to act rationally but within the bounds of their cognitive ability. In this case 'cognitive ability' acts like a 'computer black box'. It is self programmed through its experiences and available genetic structure to process information. The resultant behaviour will reflect a range of characteristics one set of which relates to the way the actors will make intertemporal choices. Observations under controlled conditions show that actors will disclose a bias towards immediacy and may re-order their future preferences (preference reversal) as they approach the relevant perceived event in time. This bias will decay over time and eventually will dissipate leaving their underlying long term preferences appropriately ranked and discounted (exponentially) into the future. The combined discounted schedules of their future utility preferences, forms their hyperbolic discount function.

The second is similar to the first except it describes the inner workings of the black box.[23] This description is provided by virtue of developments in cognitive psychology and neurological research that have been described in this paper.

In relation to intertemporal choice in economics, I would argue that the two most significant observations to be derived from the research are:

- The propensity to prefer immediacy as an event approaches appears to be a natural process in humans and other animals. The relative strength of this motivation varies

[23] W. B. Arthur's paper "Cognition: The Black Box of Economics" (Arthur,2000) provides an interesting discussion on this topic.

considerably between subjects and in its extreme form could be the result of impaired cognitive processes. Conversely in some subjects this propensity might hardly exist.

- The ability to adopt forestalling behaviour to counter natural tendencies is achieved by the subject synthesising conditions within the personal environment that results in the subject being coerced into a 'rational behaviour'. These have been described as commitment devices and may be formed by creating conscious mental constructs or the use of external cultural rules including contracts enforceable by law. Subjects that achieve a high level of forestalment are characterised as having 'strong will power' and those that do not are 'weak willed' or in Aristotle's words suffer from 'akrasia'. This view is purely subjective but the advantages associated with possessing 'will power' appear to be valued highly in most cultures although inconsistently over time.

The difficulty for the application of intertemporal theory is that it remains fundamentally a static analysis. Samuelson (1937) confronted this issue when proposing his discounted utility function where an agent will reorder their preferences potentially at each instant of time thus revealing their personal discount rate. Hyperbolic discounting recognized immediacy through introducing the parameter for personal bias. The research tends to support the model by confirming the influence of immediacy.

Cause and effect - on the balance of probability the phenomena will continue to occur unless it is disturbed. Risk is another probability that the phenomena will be disturbed. In reality forecasts remain as a set of Bayesian probabilities because future confirmatory outcomes do not yet exist. If we have a need to predict within 10 basis points what the AUD/USD exchange rate will be next Wednesday, we may compute an estimate with a certain confidence level and either accept the risk or insure.

In the midst of succumbing yet again to the gravity of some immediacy or clicking the switch of some forestalling strategy, perceptions of events in the next moment of time may cause the reordering of one's preferences in that instant. There simply is no certainty.

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