A GENERAL THEORY OF DECISIONS:
PSYCHOLOGICAL ECONOMICS

A Unified Model of Decision-making Under Uncertainty

Part I: Foundations & Individual Choice

Abstract

This paper is the first of two core articles that together comprise Psychological Economics Theory, a generalized model of decision-making under uncertainty. This first paper delineates foundations and an overview of the overall theory and establishes a new framework of individual choice. Conventional single-value lottery outcomes are omitted; agents instead face multi-period matched outcomes that contain personal total benefit (PTB) and personal total cost (PTC). They optimize an overall weighted outcome rank dependent value function against personal 'psychological trade-off constraints'. The conventional notion of economizing as an allocation of scarce resources is replaced by a dynamic individual psychological process of continuously balancing PTB and PTC. All decision-relevant information is therefore endogenous, and the concept of 'testing' is introduced, which precludes both equilibrium and persistent non-systematic disequilibrium. The second, follow-on paper, subtitled "Interaction Between Agents", will subsequently derive two fundamental outcome dynamics of interaction - joint interactions and disjoint interactions, which address observations that are difficult to explain with equilibrium models, such as repeated boom/bust and fad/counter-fad cycles. A generalized Give & Take analytical construct is established that distils economic, psychological, sociological and political theories into a unified pragmatic framework, which is theoretically grounded and more easily applied in integrated fashion. Social policy and institutions are Pareto Optimal when they facilitate 'coupling' of PTB and PTC. Four Axioms of Freedom are provided as the basis for a FreeAccountable Society, a potential next phase in the evolution of modern capitalist democracies. Tremendous opportunity exists for further application of this cross-disciplinary model.

Key words: *Cumulative Prospect Theory, Psychological Economics, Give & Take Decision Theory, Matched Outcomes, Psychological Trade-off Constraint, FreeAccountable Society*

JEL Classification A10, P00, D00, E00

Contact: admin@economicsreinvented.com
Visit: www.economicsreinvented.com

1. An Overview of Psychological Economics Theory

Psychological Economics Theory is a new, generalized model of decision-making and associated behaviour under uncertainty. It builds heavily on the fundamental insights of Cumulative Prospect Theory (Kahneman & Tversky, 1992) and Game Theory (von Neumann & Morgenstern, 1944, 1947) but significantly diverges in order to address both the theoretical and applied shortcomings of contemporary mainstream equilibrium approaches. From a theoretical perspective the model evolves decision-making from an emotionless mechanical balancing of external trade-offs, such as price and quantity or various lottery outcomes with associated probabilities. The result is a time-based process where individuals make internal psychological trade-offs of cost and benefit, bearing the former in order to obtain the latter.

The model follows in the spirit that "there is only one social science" (Hirshleifer, 1985). In the same way that the many complex dynamics of economics are distilled into the simple and powerful supply and demand analytical framework, Psychological Economics Theory pragmatically distils the complex theories from across the social sciences into a single construct. Application of this *give and take* framework allows unified analysis of the full range of economic, political and social phenomenon, including clear determination of the effectiveness of social policies and institutions. Many observations that are not sufficiently captured in mainstream models, such as boom/bust and fad/counter-fad cycles are robustly explained within Psychological Economics Theory. A strong theoretical foundation is also provided for the continued promising application of complex systems analysis to macroeconomics.

There are seven distinct foundational characteristics that distinguish Psychological Economics Theory:

- ***Matched outcomes****: Every potential outcome contains each of personal total benefit (PTB) and personal total cost (PTC) values and probabilities, not single-valued positive or negative lottery outcomes.*
- ***Semi-controllable prospects****: Personal total cost and personal total benefit each contain both certain, directly controllable and uncertain components.*
- *A* ***non-linear, cumulative rank-dependent value function*** *that individually weights the magnitudes of personal total benefit and personal total cost by the corresponding probability weighting of each, and also cumulatively weights each event by its rank dependent overall weighted value.*
- *A* ***psychological trade-off constraint*** *internal to the decision-maker that determines how much personal total cost an agent is willing to take on (including certain costs and risk) in pursuit of an additional, marginal unit of potential personal total benefit.*

- ***Give & take curves:*** *Traditional Supply and Demand curves become components of generalized Give and Take curves. Social interactions are hence explained in the context of PTB vs. PTC trade-offs, rather than simply as a trade-off between quantity and financial price.*
- ***Testing behaviour****: The existence of any level of uncertainty greater than zero eliminates the possibility of equilibrium. Wherever uncertainty exists, agents will take on small levels of personal total cost (certain and uncertain elements) to potentially uncover uncertain personal total benefit.*
- ***Time dependent cause & effect:*** *Agents have more control over their personal total cost in terms of up-front effort and outlays than they do over the associated personal total benefits that typically follow with some time delay and subject to more uncertainty through cumulative counter agent effects. Cumulative counter agent effects will be explored in a subsequent section of this writing.*

Personal total cost and personal total benefit each typically include psychological and financial perspectives. PTC is a combination of certain cost and uncertain potential cost (risk) potentially to be borne by a decision-maker in a scenario. *Matched outcomes*, the notion that replaces traditional single value (either positive or negative) lottery outcomes with outcomes that always contain each of personal total benefit and personal total cost, is a key axiom of Psychological Economics Theory. Closely related to this is the notion that agents have some control over their personal total cost and personal total benefit, and that by taking on more personal total cost, personal total benefits can most often be increased over time.

In Psychological Economics Theory the standard utility function is replaced with a value function that relies on cumulative transformations, building on insights of Cumulative Prospect Theory. In Psychological Economics Theory the weighted value of the overall outcome is cumulatively transformed, rather than the probability scale. Of tremendous significance is the introduction of a formal internal psychological trade-off constraint by which an agent determines how much personal total cost they are willing to take on and/or risk taking on for additional potential personal total benefit. Decision-making agents essentially carry out an *economizing* optimization that goes beyond simple budget constraints to include internal trade-off preferences of anticipated personal total cost versus anticipated personal total benefit. Numerous psychological drivers contribute to the existence and resilience of the internal psychological trade-off constraint, and these will be explored subsequently.

Within Psychological Economics Theory all relevant information is necessarily endogenous, the only relevant information being that as interpreted and revealed by agents. The concept of *testing* is introduced, whereby agents in the face of uncertainty typically take on small, incremental PTC (both certain and uncertain elements) to see whether they can uncover new information to improve their prospects by obtaining a priori unknown PTB.

The name of Psychological Economics Theory results from a fundamental notion that redefines the entire nature of economizing. In conventional economic thought economizing is based on the concept of scarcity, the idea that agents pursue their preferences by choosing from exogenous 'states of the world' that reflect allocations of scarce resources. Within this context, all of economics essentially becomes an allocation problem across states of nature that 'just are', often as a result of imposed equilibrium conditions. In this approach, deviations from equilibrium are temporary distortions, not fundamental driving dynamics. As such, mainstream models do not generally provide suitable explanation of the most fundamental of capitalist forces, the decision-making of the individual capitalist.

Psychological Economics Theory replaces the primary focus of economizing from one of scarcity to one of balancing personal total cost and personal total benefit. The notion of economizing is hence used to denote the fact that decision-making is an internal trade-off, an economizing decision that seeks to maximize personal total benefit while minimizing personal total cost. This truly grounds economics in psychology. In this sense, the term *Economics* denoted in Psychological Economics Theory refers more so to the internal psychologically-based economizing decision within an agent's own mindset (including instinctual, emotional and calculated elements), than it does directly to the discipline of economics as we know it. Scarcity remains an ultimate constraint, which itself differs over short-term versus intermediate-term and long-term horizons, but decisions are typically constrained by personal total cost limits before the boundaries of physical scarcity constraints apply. Psychological Economics Theory is able to robustly explain decision-making in today's highly digital economy, where the cost of information quickly declines and where free information is commonplace.

This foundation impacts the traditional approach to decision-making under uncertainty, by replacing the notion that agents evaluate an exogenous distribution of potential single value lottery outcomes with the notion that decisions are most often a determination by agents of what cost they are personally prepared to bear and/or risk bearing to potentially produce desired benefits. Some of the costs borne in pursuit of desired benefits are uncertain, but many of them are certain and controllable. Personal total cost is hence semi-controllable (containing a certain component and an uncertain component). *Risk* is characterized by the expected value and range of the uncertain component of

personal total cost. To a lesser degree, personal total benefit is also semi-controllable. The reward from risk-taking is characterized by the expected value and range of the uncertain component of personal total benefit.

In colloquial terms, decision-making is essentially an interactive multi-period balancing act for an agent of what to 'put in' in terms of certain and uncertain cost (i.e. time, money, mental/physical effort etc.) versus what the agent expects to 'get out' of the effort in return. An illustrative example is that of the decision to lose weight. An agent may consider exercise in order to obtain a number of perceived elements of personal total benefit (such as improved health, attractiveness, energy etc.) and that agent typically knows that they can exercise more and eat better in order to achieve their goal with complete certainty if they commit to the goal. There is some uncertainty surrounding the quantities of each parameter, but the agent's ability to decide and specifically control the outcomes of their decisions is generally a missing element of mainstream decision-making theory. A particular agent's PTB and PTC associations, which may even vary day-to-day, will determine how they specifically act. One agent may see the possibility of exercise as an overall personal total cost due to foregone leisure. Another agent may see the possibility of exercise as a personal total benefit in the form of invigorating activity that exceeds the perceived personal total cost of 'being lazy'.

The cornerstone of Psychological Economics Theory is that agents strive to maximize personal total benefit and minimize personal total cost, making decisions by evaluating each alternative in terms of the implied trade-off between personal total benefit and personal total cost over the entire timeframe in which these impacts occur. Since there is always an opportunity cost to an alternative, all potential outcomes contain both personal total benefit and personal total cost elements, grounding the principle of matched outcomes. In a world where agents face time constraints, material resource constraints and the constraint of having to interact with others that have their own objectives, this type of internal trade-off is what becomes most relevant in decision-making, much more so than the traditional economic choice problem of the quantities of goods and services to produce and consume.

Decision-makers will generally do their best to include past experience, current conditions and future expectations into their judgement of the personal total benefit and personal total cost they expect to occur as a consequence of a decision. A full definition of matched outcomes takes the present value of all personal total benefit and personal

total cost elements that are expected to be associated with an outcome over the relevant time frame. As will be discussed later, consideration of time horizon also introduces the possibility that decisions will be revisited, as new information comes to light and potentially changes decision inputs.

The existence of testing behaviour precludes the existence of the traditional notion of economic equilibrium, whether conceived as partial, general, fixed point, steady state, information constrained or strong-form rational expectations. In Psychological Economics Theory these various market 'clearing' concepts are replaced with two modified 'clearing' concepts; joint and disjoint interaction outcomes. Psychological Economics Theory is a cyclical outcome model, which precludes both equilibrium and persistent non-systematic disequilibria situations. The two fundamental outcome dynamics of interaction that can result in Psychological Economics Theory are *joint interactions* and *disjoint interactions*. The particular one that applies in a given situation is determined by whether or not the interaction is motivated by *direct ends* between directly dependent agents or by speculative gain across *indirectly dependent* agents.

Psychological Economics Theory is a theory of individual decision-making as well as of the implications of decision-making interaction between multiple individuals; the latter will be covered in the second core article of Psychological Economics Theory, subtitled "Interaction Between Agents". The powerful analytical concept of a *market* as used in economics is expanded, resulting in definitions of parallel but broader analytical concepts applicable to psychology, sociology and politics. The psychological parallel to a market is a *negotiation*, and instead of arriving solely at a financial price, agents in a negotiation pursue an agreement (which may include a financial price as well as broader terms). The parallel concept in politics is typically a vote, which attempts to arrive at a policy/law. From an economics perspective, the typical price/quantity trade-off and transaction is effectively expanded to reflect a broader personal total benefit/personal total cost trade-off, resulting in a generalized choice model and a generalization of the supply and demand interaction mechanism - *give and take.*

These interactions between directly dependent individuals with the intent to achieve direct ends are collectively known as joint interaction outcomes. From a society-at-large perspective, the dynamic of disjoint interaction produces social fad/counter-fad patterns, economic booms/busts, and political leaning/counter leaning trends, each

of which allow powerful analysis of social coordination between indirectly dependent individuals. This allows us to address phenomena such as moral hazard, the free-rider problem, externalities and trends in tastes. A decoupling of personal total cost from personal total benefit produces the free rider problem, as some agents are able to reap personal total benefits while others bear the associated personal total costs. Policies that decouple personal total cost from personal total benefit across too many agents can create significant societal and political challenges.

Joint interaction outcomes are characterized by predominantly random walk observations potentially interspersed with small-scale oscillating trending and reversals. Disjoint interaction outcomes are characterized by predominantly oscillating trending and reversal observations potentially interspersed with small-scale random walk occurrences. Psychological Economics Theory can also be referred to as Give & Take Economics (GTE) or Give & Take Decision Theory, with 'give' & 'take' referring in one context to an individual's balancing of personal total cost (give) and personal total benefit (take) and in another context to the interaction between individuals where one agent gives (supplies) and another takes (demands) some product or service.

Give & Take Decision Theory provides a unified and robust analytical framework in which to address the broad range of social science problems (see Figure 1). Similar to the manner in which economics has distilled many complex notions into a powerful supply and demand construct, Psychological Economics Theory allows the many powerful individual concepts of psychology, sociology, economics and political science to be pragmatically consolidated into a powerful 'give & take' construct for analysis and prediction of outcomes. Psychological Economics Theory also provides a strong theoretical underpinning that addresses shortcomings of economic equilibrium based theory and pragmatically addresses many economic observations that are difficult to explain with traditional economic models, such as boom/bust cycles. Analysis of the strength of *coupling* between PTB and PTC provides a powerful tool for the evaluation and development of social policy and mechanisms.

Give and Take Economics is a generalized theory. PTB to the demander can be much more than utility resulting from the 'quantity obtained' and PTB to the supplier can be much more than the 'price received'. PTC to the demander can be much more than the 'price paid' and PTC to the supplier can be much more than the cost of the

'quantity provided'. Under particular conditions Psychological Economics Theory reduces to become Expected Utility Theory or Cumulative Prospect Theory (depending on specification of preferences).

2. A Formalized Model

2.1 Foundations

The context of decision-making considered here is that of selecting a particular course of thought or action and all associated steps to act upon it. We build up the preference modeling of Psychological Economics Theory in similar fashion to that presented for Cumulative Prospect Theory. We specifically define;

i = a particular outcome
t = time period
+,- = positive overall outcome and negative overall outcome respectively
(+) , (-) = personal total benefit and personal total cost outcome values respectively
w = probability weighting function
v = value function
π = capacity function of individual events
Ψ = rank dependent cumulative weighting of overall weighted event values
P_i = perceived magnitude of positive element in outcome i
Q_i = perceived magnitude of negative element in outcome i
p_i = perceived probability of positive element in outcome i
q_i = perceived probability of negative element in outcome i
P^C_i = acceptable relative magnitude of positive element in outcome i
Q^C_i = acceptable relative magnitude of negative element in outcome i
p^C_i = acceptable relative probability of positive element in outcome i
q^C_i = acceptable relative probability of negative element in outcome I
Ψ^C = acceptable rank dependent cumulative weighting of overall weighted event values

Consider the finite set, S, of all conceivable potential states of the world. Each state, s_i, is defined over the relevant decision time frame, for all $0 \leq t \leq M$ and $0 \leq i \leq N$;

$$S = \begin{bmatrix} s_{0\,0}, s_{1\,0}, \ldots s_{i\,0}, \ldots s_{N\,0} \\ s_{0\,1}, s_{1\,1}, \ldots s_{i\,1}, \ldots s_{N\,1} \\ s_{0\,t}, s_{1\,t}, \ldots s_{i\,t}, \ldots s_{N\,t} \\ s_{0\,M}, s_{1\,M}, \ldots s_{i\,M}, \ldots s_{N\,M} \end{bmatrix}$$

The set of outcomes or consequences that occur with each state of the world in each period, t, is denoted by X, and each $x_{i\,t}$ within X contains PTB (positive value with its own probability) and PTC (negative value with its own probability) components. The primary value scale relevant to a decision-making agent is most often financial, but does not have to be. Agents may weigh alternatives based primarily on financial impact, time impact or other highly

personal factors, such as consistency with personal principles. The relevant time frame is defined as the set T (0, M), such that M is the last time period with a non-zero value for x_i.

$$T = \{ t_0, t_1, \ldots t_{i, \ldots} t_M \}$$

Perceived magnitude of personal total benefit is P_i, and perceived magnitude of personal total cost is Q_i. Outcomes are therefore represented as $x_i = \{ P_i, Q_i \}$. The entire set of outcomes is represented as:

$$X = \{ x_0, x_1, \ldots x_{i, \ldots} x_N \}, \text{ or } \quad X = \{ P_0, Q_0; P_1, Q_1 ; \ldots.. P_i, Q_i; \ \ldots\ldots P_N, Q_N \}$$

Personal total benefit and personal total cost are further broken down into their certain and uncertain components and considered over the entire relevant time horizon. Where subscript *A* denotes the certain element and subscript *U* denotes the uncertain but identified component, we have the following definition of the set of all outcomes, over all $0 < t < M$ and all $-k < i < N$:

$$x_i = \{ P_{A\,i\,t}, Q_{A\,i\,t}, P_{U\,i\,t}, Q_{U\,i\,t} \}$$

such that in each period, *t*, the single period outcome value is,

$$\{ P_{i\,t}, Q_{i\,t} \} = \{ P_{A\,i\,t}, Q_{A\,i\,t}, P_{U\,i\,t}, Q_{U\,i\,t} \} \text{ and } P \not\subset Q, Q \not\subset P, p \not\subset q, q \not\subset p.$$

Each potential course of action an agent may take in the face of uncertainty may result in any of a number of potential states of the world. Perceived probability of the uncertain component of personal total benefit in each period is $p_{U\,i\,t}$, and perceived probability of the uncertain component of personal total cost in each period is $q_{U\,i\,t}$. The decision-making time frame will contain the set of all periods up to the last period that contains at least one non-zero value of $p_{U\,i\,t}$ or $q_{U\,i\,t}$. The subjective probability of the components of both personal total benefit and personal total cost sum to one over the time horizon relevant to the decision at hand.

$$\sum_{t=0}^{M} \sum_{i=-k}^{N} p_{U\,i\,t} + q_{U\,i\,t} = 1$$

This condition holds because even if the decision-making agent does not accurately identify all potential outcomes, they have done their best to do so, and hence their decision will be made from the perspective that all conceivable

options have been identified. We next define the prospect function, building upon the approach utilized in Cumulative Prospect Theory:

f: S $\rightarrow$ *X*, which maps S to X, such that $f(s_{it}) = x_{it}$.

Each multi-period state of the world is an event, denoted as E_i, containing component values, E_{it} in each time period, *t*. E is a subset of S. Each event contains both perceived outcome magnitudes and associated perceived probabilities of occurrence over the relevant time period, which are interpreted via the value functions, *v*, and probability weighting functions, *w*, respectively. In the general context, when we are not concerned with whether or not the overall weighted value of a particular event is positive or negative, the functions, *v* and *w* will often be written without the overall value indicator superscript. Specifically, each event incorporates both PTB$\{w^{(+)}(p_{Uit}), v^{(+)}(P_{Ait}), v^{(+)}(P_{Uit})\}$ and PTC$\{w^{(-)}(q_{Uit}), v^{(-)}(Q_{Uit}), v^{(-)}(Q_{Ait})\}$.

In Psychological Economics Theory, a prospect is reflected through the set of potential events (P_{Ait}, Q_{Ait}, P_{Uit}, Q_{Uit}, E_{it}) for all *i* and *t* relevant to the decision at hand. This differs from the representation of a prospect as (x_i, E_i) in Cumulative Prospect Theory. In Cumulative Prospect Theory, the probability of each event, producing outcome x_i, is p_i. By contrast, in Psychological Economics Theory, the probability attached to each E_{it}, is the sum of both outcome probability components, specifically $p_{Uit} + q_{Uit}$. It is not meaningful for agents to rank individual values of P_{it} and Q_{it} in order, because they cannot be separated with respect to each event that contains them. Because events can only manifest through the uncertain outcomes of prospects, the net payoff value of $P_{it} - Q_{it}$ also cannot be meaningfully ranked. It does however make sense that agents may rank in order of preference each potential event value, E_i.

In Cumulative Prospect Theory, the weight-adjusted value of a particular event can be interpreted as $w(p_i)\, v(x_i)$. In Psychological Economics Theory, the corresponding value is:

$$E_i = \sum_{t=0}^{M} [\, v^{+(+)}(P_{Ait}) + v^{+(+)}(P_{Uit})\, w^{+(+)}(p_{Uit}) - v^{+(-)}(Q_{Ait}) - v^{+(-)}(Q_{Uit})\, w^{+(-)}(q_{Uit})\,] \quad \text{for all } E_i \geq 0$$

$$E_i = \sum_{t=0}^{M} [\, v^{-(+)}(P_{Ait}) + v^{-(+)}(P_{Uit})\, w^{-(+)}(p_{Uit}) - v^{-(-)}(Q_{Ait}) - v^{-(-)}(Q_{Uit})\, w^{-(-)}(q_{Uit})\,] \quad \text{for all } E_i < 0$$

Psychological Economics Theory requires that agents rank each overall event value relative to others, based on its overall weighted value, as opposed to the approach of Cumulative Prospect Theory, which ranks cumulative probabilities. In building a cumulative functional for Psychological Economics Theory, we arrange each event, E_i in increasing order:

$$E_0 < E_1 < E_2 < E_3 < \ldots\ldots < E_i \ldots\ldots < E_N$$

On this foundation, the overall event value weighting function, Ψ_i, will be defined subsequently, based on the difference in the capacities (non-additive generalization of relative overall weighted value) of E_i and E_{i+1} as they both relate to ΣE. The decision-making mechanism itself is a process whereby agents must impose a mental model on a situation for which they cannot observe underlying actual empirical outcome alternatives. Agents have to consider and consolidate a vast number of unknown potential alternative states of the world and associated probability distributions, into a group of manageable categories, represented by $w^{(+)}(p_{Uit})$, $w^{(-)}(q_{Uit})$, $v^{(+)}(P_{Uit})$, $v^{(+)}(P_{Ait})$, $v^{(-)}(Q_{Uit})$, $v^{(-)}(Q_{Ait})$ and overall weighting function Ψ_i. This incorporates the demonstrated psychological principle of *compartmentalizing*; a process based on each agent's own experience and judgement, and may or may not have much correlation to any actual empirical values that result.

The variables P_{Ait}, Q_{Ait}, P_{Uit}, Q_{Uit}, E_{it}, p_{Uit}, q_{Uit} are each subjective variables that only take on values as interpreted by each agent via the probability weighting functions, $w^{(+)}(p_{Uit})$, $w^{(-)}(q_{Uit})$, the value functions $v^{(+)}(P_{Ait})$, $v^{(+)}(P_{Uit})$, $v^{(-)}(Q_{Ait})$, $v^{(-)}(Q_{Uit})$ and Ψ_i. None of these variables exist in an empirical system absent of some agent's interpretation. Agents must make a judgement about the most likely value and range of values that can occur for each. The functions *w*, *v* and *Ψ* all incorporate a monotonic time discounting element that places higher weighting on more immediate PTB and PTC. When making decisions, agents make judgements about those components of personal total cost and personal total benefit about which they feel certain and those about which they are not certain, but regarding which they must form a probability weighted expectation.

Comonotonic prospects provide rank-dependence and preserve the same desirability ordering of states of nature (events) in all prospects, ensuring that preferences do not depend on common consequences, unless a common

consequence, when substituting it in place of another, alters the rankings of the outcomes. Sign-dependence allows different decision weights to be applied to events that result in incremental gain versus those that produce incremental loss. The sign-comotonic trade-off specification essentially allows meaningful value comparison of prospects as long as they have the same sign and are also comonotonic. This criterion is important because it ensures that the weight attached to each state is the same for all prospects (Wakker & Tversky, 1993).

In order to model the full set of rich inferences possible in Give & Take Decision Theory, such as optimism, pessimism, risk appetite, diminishing sensitivity and time value discounting, and in order to ensure consistent preference inferences, since weightings differ for the various components of weighted event values, the conditions of rank dependence and sign-dependence at the weighted event value level are generalized into the concept of *sign-tiered-comonotonic trade-off consistency* (STCTC). This criterion requires direct and relative comonotonicity. Specifically, $w^{(+)}(p_{U\,i\,t})$, $v^{(+)}(P_{A\,i\,t})$ and $v^{(+)}(P_{U\,i\,t})$, are comonotonic increasing, $w^{(-)}(q_{U\,i\,t})$, $v^{(-)}(Q_{U\,i\,t})$ and $v^{(-)}(Q_{A\,i\,t})$ are comonotonic decreasing, and each of the elements that comprise event values, $w^{(+)}(p_{U\,i\,t})$, $w^{(-)}(q_{U\,i\,t})$, $v^{(+)}(P_{A\,i\,t})$, $v^{(+)}(P_{U\,i\,t})$, $v^{(-)}(Q_{U\,i\,t})$, $v^{(-)}(Q_{A\,i\,t})$, maintain the same relative ordering to each other (desirability ranking) in all states.

These conditions ensure meaningful inferences, providing for a strictly increasing value function, and strictly increasing psychological trade-off constraint. Utilization of a traditional exponential time weighting over the decision relevant time frame also effectively builds in time horizon comonontonicty. The result of this psychological foundation and the axioms elaborated subsequently, is a preference ordering of prospects in Psychological Economics Theory that is ordinally ranked, transitive, complete, sign-tiered-comonotonic trade-off consistent and maintains stochastic dominance.

Psychological Economics Theory delineates a 'fully-specified' model of decision-making for agents. When STCTC holds true, we are able to make robust inferences from an agent's preferences. It is however vital to note that the mathematical condition of STCTC is very restrictive and essentially just defines the conditions required to ensure that we can mathematically make consistent inferences with respect to preferences. In practice, agents have assigned their weighting values, allowing inferences between preferences to be easily carried out in a full range of situations, not just those that meet STCTC conditions.

An agent may not be able to fully ascertain all components of PTB and/or PTC in the face of various prospects in real world decision-making scenarios. Agents must pragmatically make decisions based on the most robust understanding they can form in a particular situation. It is for this reason that Give and Take Decision Theory employs rank dependence at the overall weighted outcome value, because, when a more specific breakdown of prospects is not possible at the level of certain and uncertain components, agents will 'make do' with their judgement of the overall event value, total PTB and total PTC.

A prospect is fully represented and valued, over all relevant values of *i* and *t*, as follows:

$$f = \sum_{t=0}^{M} \{ \sum_{i=0}^{N} [v^{+(+)}(P_{Ait}) + v^{+(+)}(P_{Uit})\ w^{+(+)}(p_{Uit}) - v^{+(-)}(Q_{Ait}) - v^{+(-)}(Q_{Uit})\ w^{+(-)}(q_{Uit})] + \sum_{i=-k}^{-1} [v^{-(+)}(P_{Ait}) + v^{-(+)}(P_{Uit})\ w^{-(+)}(p_{Uit}) - v^{-(-)}(Q_{Ait}) - v^{-(-)}(Q_{Uit})\ w^{-(-)}(q_{Uit})] \}$$

The following set of axioms characterize the preference structure of Psychological Economics Theory. In establishing these axioms we rely heavily upon previously delineated axiomatization for Cumulative Prospect Theory (Wakker & Tversky, 1993). Consider the set of all decision-relevant prospects, G, endowed with a connected product topology, where $\succsim$ and $\precsim$ are binary preference relations on G. We define F ($F \in G$) and two subsets; F^+ which contains all prospects where $f \geq 0$ and F^- which contains all prospects where $f < 0$. F is the additive subset, which allows consistent inferences about preference relations. F is defined as the subset that meets the following two primary conditions;

1) a permutation of the state space, $\Phi(i)$ exists, such that event values are arranged in increasing order $f(E_1) \precsim f(E_2) \precsim \ldots f(E_i) \precsim \ldots f(E_N)$, and,
2) for each prospect the positive part lives on A [ie. f^+ lives on A, such that $f(i) \precsim 0$ for all $i \in A^C$] and the negative part lives on the complement of A, A^C [ie. f^- lives on A^C, such that $f(i) \succsim 0$ for all $i \in A$].

Condition (1) provides for rank dependency and condition (2) provides for sign-dependency. Each prospect, *f*, is assigned a value V*(f)*, such that prospect *f* is preferred to or indifferent to prospect *g* if and only if V *(f)* ≥ V *(g)*. In addition to the standard axioms of completeness, continuity and transitivity, over any period $0 < t < M$, for all values of $-k < i < N$, and for any prospects $f, g \in F$, the following additional axioms are defined:

Matched Outcomes

When $\sum_{t=0}^{M} v^{(+)}(P_{Ait}) + v^{(+)}(P_{Uit}) > 0$, it holds that $w^{(+)}(p_{Uit}) > 0, \sum_{t=0}^{M} v^{(-)}(Q_{Ait}) + v^{(-)}(Q_{Uit}) > 0$ & $w^{(-)}(q_{Uit}) > 0$

Sign Tiered-Comonotonic Trade-off Consistency

The *sign-tiered-comonotonic trade-off consistency* (STCTC) criterion requires direct and relative comonotonicity and sign dependence. Specifically, $w^{(+)}(p_{Uit})$, $v^{(+)}(P_{Ait})$, $v^{(+)}(P_{Uit})$ are comonotonic increasing, $w^{(-)}(q_{Uit})$, $v^{(-)}(Q_{Uit})$ and $v^{(-)}(Q_{Ait})$ are comonotonic decreasing, and each of these elements that comprise event values are comonotonic independent from each other, and maintain the same relative ordering (desirability ranking) in all states. These conditions allow meaningful inferences, by ensuring consistent ordering of utility intervals. They underpin a strictly increasing value function and strictly increasing psychological trade-off constraint. Utilization of a traditional exponential time weighting over the decision relevant time frame also effectively builds in time horizon comonontonicty.

Relative Certainty Preference (Personal Total Cost Aversion)

Wherever all inputs other than $w^{(-)}(q_{Uit})$ are fixed and where $w^{(-)}(q_{Uit})$ is lower in *f* than it is in *g*, then $f > g$. *T*his axiom extends the standard concept of risk aversion to become one of *Personal Total Cost Aversion*.

Time Dependent Cause & Effect

$$\sum_{t=0}^{M} t \text{ where } \{v^{(+)}(P_{Ait}) + v^{(+)}(P_{Uit})\} > 0 \quad > \quad \sum_{t=0}^{M} t \text{ where } \{v^{(-)}(Q_{Ait}) + v^{(-)}(Q_{Uit})\} > 0$$

This axiom captures the notion that agents in general have more immediate control over and face more immediate impact on their personal total cost in terms of upfront effort than they do over the personal total benefits that typically follow with some time delay and being subject to more uncertainty due to cumulative counter agent effects.

Psychological Economics Theory does not structurally require that $p_{Uit}, q_{Uit} > 0$ in all outcomes to be an applicable theory to most decision-making scenarios. It may be possible to construct potential theoretical outcomes that contain no personal total cost and/or no personal total benefit, essentially 'infinite cost lunch' or 'free lunch' outcomes. However, these outcomes are certainly not typical and numerous in practice.

A strong argument that $p_{Uit}, q_{Uit} > 0$ in all outcomes is the assertion that every outcome that could materialize, would by definition preclude alternative outcomes, which means some lost opportunity and some avoided cost. The fundamental economic concept of opportunity cost illustrates very effectively that decision-making itself is a non-trivial endeavour because a decision requires an alternative (opportunity) cost to be borne, whether the decision is to act or to remain in status quo. In addition, the ever-present existence of uncertainty, a reality that itself is the major driver of the need for decision-making theory, always introduces a discomfort (personal total cost) element, whether through an explicit decision to change or to try to maintain the status quo. The latter is still a decision and is subject to the uncertainty that it might not prevail despite best efforts.

2.2 The Psychological Economics Theory Value Function

Each prospect, *f*, is assigned a value V *(f)*, such that prospect *f* is preferred to or indifferent to prospect *g* if and only if $V(f) \geq V(g)$. Each prospect represents a potential alternative decision/course of action, and as such, agents will value the set of possible prospects and select the one that results in the highest V*(f)*. Where λ represents the decision to be made, it can be understood as:

$\lambda = \text{Max } V(f)$

The Psychological Economics Theory value function is a strictly increasing function, defined as follows:

$V(f) = V^{+}(f) + V^{-}(f)$

$$V(f) = \int_{t=0}^{M} \{ \int_{i=0}^{N} [w^{+(+)}(p_{Uit})\, v^{+(+)}(P_{Uit}) + v^{+(+)}(P_{Ait}) - w^{+(-)}(q_{Uit})\, v^{+(-)}(Q_{Uit}) - v^{+(-)}(Q_{Ait})]\, \Psi^{+}_{i} + \int_{i=-k}^{-1} [w^{-(+)}(p_{Uit})\, v^{-(+)}(P_{Uit}) + v^{-(+)}(P_{Ait}) - w^{-(-)}(q_{Uit})\, v^{-(-)}(Q_{Uit}) - v^{-(-)}(Q_{Ait})]\, \Psi^{-}_{i} \}$$

The fact that outcomes are matched-valued (contain both PTB and PTC) in Psychological Economics Theory, with different probability weightings and value magnitude interpretations attributed to each, means that it is not possible to rank each value of x_i directly in increasing order. It is therefore not necessary that when $i > j$, $x_{it} > x_{jt}$.

Psychological Economics Theory does not require that probabilities be transformed by a cumulative subjective weighting function in the same way that they are for Rank Dependent Utility and Cumulative Prospect Theory. However, in order to ensure that rank dependence, monotonicity and stochastic dominance are preserved, a cumulative transformation is applied to the overall weighted value of each event, E_i. In Cumulative Prospect Theory, each outcome, x_i, …. x_N, is ranked in increasing order with individual probabilities matched one to one to each outcome value. Weighting is then represented by a non-linear transformation of probabilities, the weight for each outcome reflecting the 'marginal' probability, which can be interpreted such that a particular outcome value is "likely to be at least as good as" those that precede it in the ranking.

In Psychological Economics Theory, the overall weighting function is represented by the overall weighted value of each event, E_i, relative to other potential events. The weighting applied at each value, *i*, through the function Ψ, is therefore the incremental overall weighted value obtained, reflecting that the overall weighted outcome value is "at least as good as" those that precede it in the ranking of overall weighted outcome values. The GTE value function is structured in similar fashion to that of CPT. Specifically, events are considered as gains or losses relative to a reference point, generally the status quo, allowing for differing attitudes toward losses and gains. The GTE value function is also generally concave for gains and convex for losses, capturing diminishing sensitivity toward PTB.

Risk aversion and variability seeking behaviour will be discussed subsequently in detail, but we can at this point identify two key traits of the GTE value function that do underpin inherent overall risk aversion in decision-making agents, ceterus paribus. Firstly, the losses portion of the curve is convex, implying that people are motivated more

by losses than by gains and as a result will devote more energy to avoiding loss than to achieving gain. Secondly, the value function is steeper for losses than it is for gains.

The cumulative weighting function, Ψ , employed in Psychological Economics theory shares a number of structural characteristics with the probability weighting function utilized in CPT. Most notably, the cumulative weighting function, Ψ, is S-shaped, concave near zero and convex near unity. Outcomes close to the status quo get less weighting relative to extreme values. In CPT, the S-shape of the probability weighting function implies that small probabilities are generally over weighted and that moderate to high probabilities are generally under weighted. As a result, in CPT, risk aversion behaviour is typical for gains of high probability and losses of low probability, whereas *variability seeking* behaviour is typical for gains of low probability and losses of high probability.

In Give and Take Decision Theory, the s-shape of Ψ implies a relative over weighting of small probabilities and higher outcome magnitudes and a relative under weighting of high probabilities and smaller outcome magnitudes. This asymmetry produces relative high risk aversion for low probability losses with large magnitude and for high probability gains with small magnitude. For example, agents often prefer to bear a higher probability or even fully known loss in order to avoid the possibility of a relatively remote loss with large magnitude. Agents will also typically not pursue risk to obtain gains that are small, even if the probability of attainment is large. They just don't see a worthwhile 'big payoff'.

This asymmetry also produces variability seeking behaviour for large magnitude gains with low probability and for small magnitude losses of high probability. As an illustrative example, agents often prefer to forego high probability low to moderate magnitude gains in pursuit of large, but remote upside payoffs; they are willing to gamble in giving up some certain positive outcome for a chance at significantly larger upside. Agents are also very willing to bear risk when the probability of loss is small to moderate, so that they may avoid low probability but high magnitude losses that can be devastating.

Because the GTE weighting function, Ψ, includes multiplication by outcome magnitudes, it's S-shape will be 'vertically stretched' relative to the s-shape of the probability weighting function employed in CPT. The trade-off

dynamics concerning sensitivity and variability attitudes discussed to this point do not yet explicitly incorporate the impact of time horizons and sustained effort on the PTB/PTC trade-off. Over longer time horizons, the psychological trade-off constraint transitions from generally concave to convex and back to concave, as sensitivity and risk aversion interplay with cumulative counter agent effects. This dynamic will be discussed thoroughly in a subsequent section. The following weighting functions are defined in Psychological Economics Theory, assigning a weight based on the difference between two capacity functions (Choquet, 1955):

$$\Psi_i^{+} = \pi^{+}\left(E_{i+1} \Big/ \sum_{i=-k}^{N} E_i + \ldots + E_N \Big/ \sum_{i=-k}^{N} E_i\right) - \pi^{+}\left(E_i \Big/ \sum_{i=-k}^{N} E_i + \ldots + E_N \Big/ \sum_{i=-k}^{N} E_i\right) \quad \textit{for all } 0 \le i \le n-1$$

$$\Psi_i^{-} = \left[\pi^{-}\left(E_{-k} \Big/ \sum_{i=-k}^{N} E_i + \ldots + E_i \Big/ \sum_{i=-k}^{N} E_i\right) - \pi^{-}\left(E_{-k} \Big/ \sum_{i=-k}^{N} E_i + \ldots + E_{i-1} \Big/ \sum_{i=-k}^{N} E_i\right)\right] \quad \textit{for all } -k+1 \le i \le 0$$

$$\Psi_i^{+} = \pi^{+}\left(E_N \Big/ \sum_{i=-k}^{N} E_i\right) \quad \textit{for } i = n \quad \textit{and} \quad \Psi_i^{-} = \left[\pi^{-}\left(E_{-k} \Big/ \sum_{i=-k}^{N} E_i\right)\right] \quad \textit{for } i = -k$$

2.3 The Psychological Constraints

Psychological Economics Theory postulates that agents optimize by making trade-off decisions in the face of their own internal psychological constraint. The addition of a psychological constraint is a significant diversion from traditional economic thought on how agents make decisions. In the approach of Psychological Economics Theory, external constraints, such as budget, are always considered to have their impact on utility indirectly, through interpretation by the agent, based on that agent's personal psychological constraint. Consider for example the constraint of a particular current budget that is very low relative to the purchase desires of an agent. Some agents may choose to lower consumption to compensate, some may borrow, and some may shift additional consumption to investment in an attempt to raise the budget constraint over time.

Real world decisions occur in an environment where agents face an aggregation of correlated and uncorrelated factors and must sort through them as best as they can. Agents must weigh opportunity versus risk in an uncertain world and decide on a trade-off that meets their personal comfort level, bearing *both* personal total cost and personal total benefit in all outcomes at some point in the time frame relevant to the decision and its associated actions.

Popular culture has many expressions that capture this observed reality, such as ‘getting out what you put in’, ‘no pain, no gain’, ‘bearing the fruit of one’s labour’.

Mainstream approaches to decision-making generally do not capture this fundamental element because they utilize simple single-value outcome lottery experiments. Such an approach does not capture the underlying conditions of decision-making. Whereas the traditional budget constraint allows tangible trade-off through observed prices, the psychological trade-off constraint reflects an individual’s ‘personal psychological trade-off terms’ or ‘price’, capturing how willing they are to bear personal total cost to obtain personal total benefit. Each agent formulates these expectations based on their set of life experiences. Life experiences impact an agent’s anticipation of magnitudes [$v^{(+)}(P_{U\,i\,t})$, $v^{(-)}(Q_{U\,i\,t})$, $v^{(+)}(P_{A\,i\,t})$, $v^{(-)}(Q_{A\,i\,t})$] and probability weightings [$w^{(+)}(p_{U\,i\,t})$, $w^{(-)}(q_{U\,i\,t})$] in all prospective situations as well as the acceptable level of PTB vs. PTC. The slope of the trade-off curve therefore represents the marginal rate of PTB that is required in order to take on an additional unit of PTC.

The nature of the optimization decision will be elaborated subsequently, but at this point it is helpful to clarify the distinct roles played by the value function, *v*, and the psychological trade-off constraint, *c*. The value function represents an agent’s judgement of the particular prospects they face when making a decision, in terms of what specific events may occur and what particular PTB and PTC are associated with each event. The value function essentially compares the particular prospects, via their component events, that the decision-maker anticipates they may face with some likelihood. By contrast, the psychological trade-off constraint directly conveys a decision-maker’s preferences, depicting the amount of PTB that is required in order for an agent to take on an additional unit of PTC or similarly the PTC that an agent will bear in order to obtain an additional unit of PTB. The concept of the PTB^C/PTC^C ratio is therefore defined by the psychological trade-off curve, which is also dependent upon the overall outcome value E, necessitating weighting by Ψ^C_i. The resulting optimization dynamic between *v* and *c* is therefore one in which anticipated prospects are evaluated, via *v*, and compared to acceptable scenarios, via *c*.

Prospect Theory and Cumulative Prospect Theory, each developed by Amos Tversky and Daniel Kahneman, most aggressively introduced the powerful tools of psychology to economic decision-making. Psychological Economics Theory follows on that path, recognizing in addition that agents’ own internal associations of personal total cost and

personal total benefit serve as a constraint similar to a budget constraint in traditional models. The approach of Psychological Economics Theory essentially expands the purely scarcity driven need for trade-off to a broader need for trade-off based on the full psychological drivers of the agent. In current economic thinking it can seem counterintuitive that agents would impose a constraint on themselves; it seems rational that an agent would immediately redefine their personal total cost and personal total benefit associations so that they could increase personal total benefit and reduce personal total cost. A number of related psychological factors discussed subsequently demonstrate that such a redefinition of associations is in fact possible, but typically takes extended periods of time and faces strong internal resistance. An agent's acceptable level of PTC^C typically includes a selection about what price to pay, what certain effort to put forth and what level of risk to bear.

In a theoretical world where agents can have whatever they want without cost they would be able to obtain infinite utility, or $V(f) = \infty$. The real world however, presents agents with a very different set of circumstances, reflecting two primary external 'barriers' to the infinite utility scenario. The first is the constraint of physical world factors, including scarcity, such as the fact that food needs to be created at some point before it can be eaten. The second is the constraint that the decision-maker cannot act unilaterally; they must interact with other agents that control resources, possess their own views, and are in turn seeking to maximize their own utility. This second type of constraint is captured in the concept of *Cumulative Counter Agent Effects*. At first this distinction seems trivial, but it is of fundamental importance, given that it is a key driver of group behaviour and largely underpins the phenomenon of trending. Whether a decision-maker thinks the position of potential counter parties is rational or not, the decision-maker generally knows that they can only influence it, that they must essentially take the position as a given and optimize against it as an 'almost' exogenous input in the short to intermediate term.

Theorem – Cumulative Counter Agent Effects
In applied decision-making situations agents know that they typically have a very small subset of potential information relevant to a decision, including the cumulative motives and positions of others. As a result, they group potential factors into easy to work with categories, reflecting the psychological concepts of compartmentalization and distinction bias. Agents behave in this manner based on the fact that they must interact in a world that reflects the motives of many others. Cumulative counter agent effects serve as a constraint in the decision-making process, not an immovable exogenous constraint, but one against which the agent can only have incremental influence, gradually over time.

Even though agents cannot always explicitly identify quantifiable decision inputs, in terms of personal total cost and personal total benefit, they generally make decisions based on their best possible approximations, through the effort

of compartmentalizing based on experience. The principle of cumulative counter agent effects reflects the 'system' nature of many interacting agents, wherein the aggregate impact of the iterative actions of many agents acting on beliefs that have been incrementally built up over time creates a slow moving system in which the influence of a particular decision-making agent and a particular decision is itself small and incremental. The 'system' of interaction is not static. It will ebb and flow and move as the iterative impacts of individuals build in particular directions. In addition, because all agents within the system are acting in self-interest, the principle of cumulative counter agent effects also means that the system will incrementally move against any agent that does not assertively act in their own self-interest or have someone do so on their behalf. A very important corollary follows from the theorem of Cumulative Counter Agent Effects, known as the principle of *Return on Cumulative Effort*.

Corollary – The Principle of Return on Cumulative Effort
The Principle of Return on Cumulative Effort establishes that decision-makers generally realize that more personal total cost is typically required to obtain more personal total benefit, and that higher levels of personal total benefit can be obtained in the long-run, as a result of a sustained investment of well-directed personal total cost. This is what drives an agent to incrementally and gradually push forward with decisions and actions to eventually achieve their longer-term objectives.

Not only do many decision-makers generally make the critical realization that more personal total cost is typically required to obtain more personal total benefit, there is often also an understanding that, in general, overall higher values of personal total benefit are possible in the long-term versus the short-term. This reflects an understanding of the notion of increased return on cumulative effort, due to practice and experience. As a result, the *Personal Total Benefit / Personal Total Cost Trade-off Curve (Psychological Trade-off Curve)*, will now be formally defined, representing the first fundamental psychological constraint in Psychological Economics Theory. It maps personal total cost to personal total benefit. Over the relevant time period $0 < t < M$ and for all $-k < i < N$, we define the psychological trade-off constraint function, c, such that:

$$PTB^{C} = c\,(PTC^{C})$$

The specific functional form is:

$$c_{i} = [\ PTB^{C}{}_{i\,t}\ /\ PTC^{C}{}_{i\,t}\ ]\ \Psi^{C}{}_{i}$$

or more specifically,

$$c_i: [PTC^C\{w^{(-)}(q^C{}_{Uit}),v^{(-)}(Q^C{}_{Uit}),v^{(-)}(Q^C{}_{Ait})\},\Psi^C{}_i]\rightarrow[PTB^C\{w^{(+)}(p^C{}_{Uit}),v^{(+)}(P^C{}_{Ait}),v^{(+)}(P^C{}_{Uit})\}]$$

or equally,

$$c_i = \{ [w^{(+)}(p^C{}_{Uit}) v^{(+)}(P^C{}_{Uit}) + v^{(+)}(P^C{}_{Ait})] / [w^{(-)}(q^C{}_{Uit}) v^{(-)}(Q^C{}_{Uit}) + v^{(-)}(Q^C{}_{Ait})] \} \Psi^C{}_i$$

In this formulation, ***c***, like *v*, is a positive, continuous, strictly increasing function that conveys the perceived trade-off of personal total cost in pursuit of personal total benefit over the relevant time horizon. In general, to achieve higher values of V(*f*) in the longer term, agents recognize that in the short-term they will face lower values of V(*f*) as constrained by lower values of c(*f*). Agents also impose a personal total cost threshold constraint. The second fundamental psychological constraint in Psychological Economics Theory is the personal total cost threshold:

Local Personal Total Cost Threshold (PTCT) is defined such that:

$$\text{Max } [PTC^C\{w^{(-)}(q^C{}_{Uit}),v^{(-)}(Q^C{}_{Uit}),v^{(-)}(Q^C{}_{Ait})\},\Psi^C{}_i]$$

Only decisions with expected (PTB, PTC) pairs above the personal total benefit / personal total cost curve will be considered, such that a selected maximum personal total cost threshold, PTCT, is not exceeded, where:

Figure 1: *Trade-off between PTB and PTC over relevant time horizon t [0,M]- The 'Leaning X'*

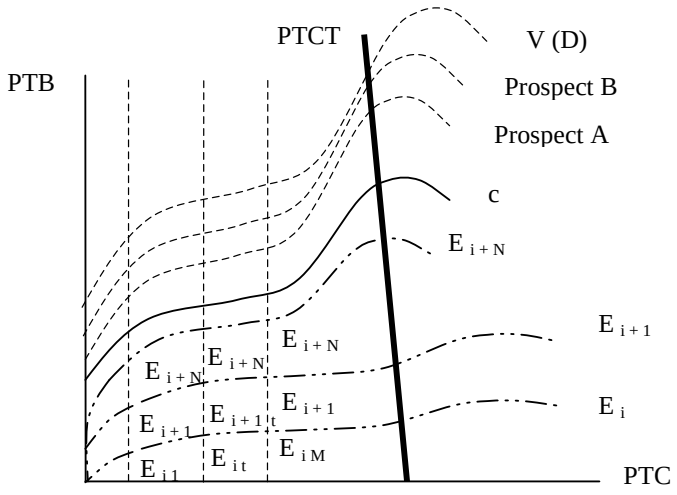
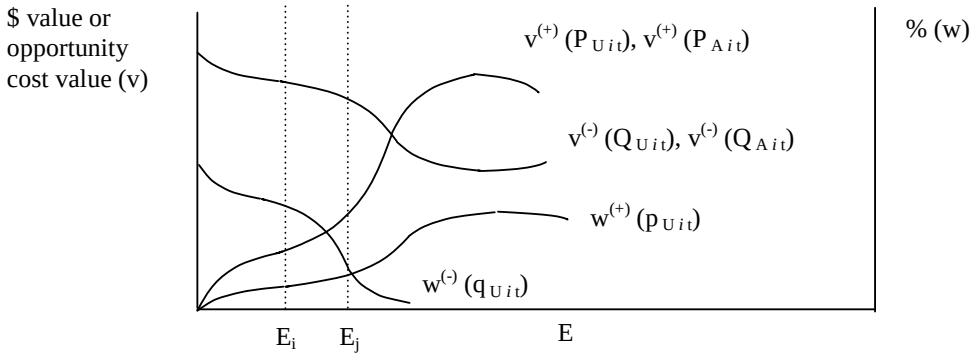


Figure 1 is a core diagram in Psychological Economics Theory, and frequent reference will be made to this 'Leaning X'. It shows the relationship of $PTB\{w^{(+)}(p_{Uit}), v^{(+)}(P_{Ait}),v^{(+)}(P_{Uit})\}$ and $PTC\{w^{(-)}(q_{Uit}),v^{(-)}(Q_{Uit}),v^{(-)}(Q_{Ait})\}$

over all values of *i* and *t*. What is of relevance to the decision-maker is the discounted present value of all future periods (up to M) back to the decision-making period, which means that the functions *v*, *w* and Ψ each contain a time discounting element. In the Leaning X depiction, the value function is plotted to illustrate its components of PTC and PTB at each level of V(*f*) rather than the traditional view of V(*f*) at each outcome value, as utilized in CPT. Whereas the trade-off curve, *c*, represents a range of normal conditions, the PTCT represents conditions where an agent is setting their personal 'break point'. This is a psychologically determined value, and agents may find themselves in fact resetting their own 'break point'. The PTCT line has slightly negative slope to capture diminishing sensitivity that exists even when an agent sets an internal maximum threshold. An agent's PTCT will often differ in the long run and short run and over various conditions (including endowment levels).

Travelling North West along the PTCT curve results in higher levels of personal total benefit relative to personal total cost, meaning that as an agent has more personal total benefit, they are less open to taking on more maximum personal total cost. Travelling South East along the PTCT curve results in higher levels of personal total cost relative to personal total benefit, meaning that as an agent has less personal total benefit they are more open to take on more personal total cost in order to obtain even small amounts of additional personal total benefit, accepting a higher PTCT. As will be demonstrated subsequently, the slope of *c* is determined significantly by the impact of cumulative counter agent effects and return on cumulative effort.

Figure 2: *Typical slopes of* $w^{(+)}(p_{Uit})$, $w^{(-)}(q_{Uit})$, $v^{(+)}(P_{Uit})$, $v^{(-)}(Q_{Uit})$, $v^{(+)}(P_{Ait})$, $v^{(-)}(Q_{Ait})$ *over E, where* $E_i < E_j$.

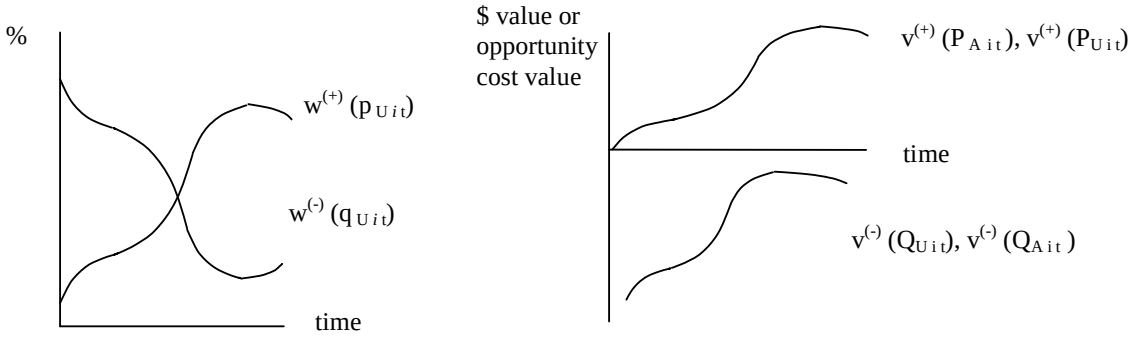


Agents generally have to decide how much personal total cost (effort, spend, foregone opportunity etc.) a particular decision and associated course(s) of action require, with the expectation that some potential personal total benefit will result. This is not to say that agents can exactly determine PTC, since external influences will impact their estimation. External impacts, especially over extended periods of time, will introduce a margin of risk to PTC.

As discussed earlier, each of personal total benefit and personal total cost typically contain both certain and uncertain components. Because agents directly control a significant portion of their effort and expenditure, the amount of personal total cost one bears is usually more certain than personal total benefit, the latter generally being impacted by the efforts/expenditures of other agents, which are less certain to the decision-maker and reveal themselves through Cumulative Counter Agent Effects. Whenever new information or other factors impact the parameters of the decision model, a new decision is required and the decision-making process is repeated.

For modeling purposes, with respect to a decision at hand, $v^{(+)}(P_{A\,i\,t})$, $v^{(+)}(P_{U\,i\,t})$ and $w^{(+)}(p_{U\,i\,t})$ are assumed to be continuous and strictly increasing over time throughout most of their range, whereas $v^{(-)}(Q_{U\,i\,t})$, $v^{(-)}(Q_{A\,i\,t})$ and $w^{(-)}(q_{U\,i\,t})$ are assumed to be continuous and strictly decreasing over time throughout most of their range. Figure 3 show's these relationships. The particulars of the slope of these functions will be discussed in further depth subsequently.

Figure 3: *$w^{(+)}(p_{U\,i\,t})$, $w^{(-)}(q_{U\,i\,t})$, $v^{(+)}(P_{A\,i\,t})$, $v^{(+)}(P_{U\,i\,t})$, $v^{(-)}(Q_{U\,i\,t})$, $v^{(-)}(Q_{A\,i\,t})$ profiles over time*



Endowments, reflecting wealth levels, impact the nature of the psychological trade off relationship. As wealth levels increase, a higher level of personal total benefit naturally flows to the agent in most decision scenarios,

resulting in a higher marginal rate of trade-off of personal total benefit required for each additional unit of personal total cost. This reflects the principle of diminishing sensitivity to personal total benefits.

2.4 Characterizing Attitudes Toward Risk & Personal Total Cost

The vast majority of decision-making models that address uncertainty rely solely on the assumption of risk aversion. However, empirical research has demonstrated that this formulation does not account for the observed asymmetry between attitudes toward gains versus losses, an asymmetry that exceeds what can be adequately explained via income effects or an assumption of decreasing risk aversion (Tversky and Kahneman, 1979).

Decisions that reflect 'risk-seeking' behaviour are observed in two common situations. Decision-making agents often exhibit preference for a relatively small possibility of obtaining a relatively large positive outcome value over the expected value of the prospect overall. Risk-seeking behaviour is also common in situations where decision-making agents are able to choose between a completely certain loss and a substantial probability of a larger loss (Tversky and Kahneman, 1979). This latter 'risk seeking' behaviour reflects an agent's desire to try to avoid the certain loss if at all possible.

The vast majority of economic models equate risk to variability. Variability is a mathematical measurement, which includes risk through potential personal total cost, and potential rewards from taking on that risk in the form of personal total benefit. Risk is truly however only the potential of uncertain personal total cost to the agent. Reward from risk, or 'upside', is not risk, even though it is a component of variability. Psychological Economics Theory therefore makes the distinction that risk is only that part of variability that is believed to potentially result in personal total cost to the agent. Some key definitions result:

Variability = Uncertainty
Variability = Risk + Reward From Risk
Risk < Variability
Risk = $PTC_R \{w^{(-)}(q_{U\,i\,t}), v^{(-)}(Q_{U\,i\,t})\}$

Associated with the uncertain components of PTC and PTB are distributions of potential values. With this perspective in mind, it is clear that agents are never truly risk seeking, but can instead be variability seeking. They

will seek the reward from risk, prepared to bear the risk as a necessary cost. Cummulative Prospect Theory captures the existence of both risk aversion and risk seeking (variability seeking) behaviour by providing that risk seeking/risk aversion dynamics are jointly determined by the value function and the probability weighting function. Psychological Economics Theory broadens the scope of consideration even further in order to model both attitudes toward risk as well as attitudes toward personal total cost aversion - the latter including risk and certain PTC.

As a result, in GTE, overall PTC aversion is determined by the *PTC Tolerance Ratio*, $1/c'$. This ratio captures how much additional PTC one will take on in order to obtain an expected additional unit of PTB.

Personal Total Cost Tolerance Ratio = $1 / c'$

Variability seeking/risk aversion are determined by the *Risk Tolerance Ratio*, $1/r'$, which isolates the uncertain component of PTC. To isolate the agent's attitude toward risk from overall variability, we remove the certain components, transforming the personal total cost tolerance ratio by isolating the uncertain elements of personal total cost and personal total benefit. Risk perspectives have a time profile, so the entire decision time horizon must be considered. We therefore define over all values of i, where $-k < i < N$ and t, where $0 < t < M$,

$$r\text{:}\ PTC_R \{w^{(-)}(q_{U\,i\,t}), v^{(-)}(Q_{U\,i\,t})\} \rightarrow PTB_R \{w^{(+)}(p_{U\,i\,t}), v^{(+)}(P_{U\,i\,t})\} \,\&\, PTC_R \{w^{(-)}(q_{U\,i\,t}), v^{(-)}(Q_{U\,i\,t})\} < PTCT_R$$

This provides a definition of the agent's risk tolerance ratio:

Risk Tolerance Ratio = $1 / r'$

The value function, v, the probability weighting function, w, and the overall rank dependent outcome weighting function, Ψ, each contribute as components into $1/c'$ *and* $1/r'$. Breaking risk and PTC acceptance attitudes into these components allows rich modeling of the relative influence and interaction of risk preference and sensitivity to PTC and PTB levels. An agent's attitude toward risk reflects the interplay of judgements about gains versus losses, outcome magnitudes, probabilities, distance from reference point (such as the status quo), as well as current and expected endowments.

As discussed previously, two key traits of the GTE value function are taken from CPT, in order to underpin inherent natural overall risk aversion in decision-making agents, ceterus paribus. Firstly, over most of its range the losses portion of the curve is convex, implying that people are motivated more by losses than by gains and as a result will devote more energy to avoiding loss than to achieving gain. Secondly, the value function is steeper for losses than it is for gains. These factors are themselves impacted by the time horizon under consideration.

Over longer time horizons of consideration, the value function and the psychological trade-off function each transition from generally concave to convex and back to concave, as sensitivity and risk aversion interplay with cumulative counter agent effects. The time profile of preferences will be detailed significantly in a subsequent section of this writing. In CPT, the S-shape of the probability weighting function implies that small probabilities are generally overweighted and that moderate to high probabilities are generally underweighted. As a result, in CPT, risk aversion behaviour is typical for gains of high probability and losses of low probability, whereas variability seeking behaviour is typical for gains of low probability and losses of high probability. In Give and Take Decision Theory, the s-shape of Ψ implys a relative overweighting of small probabilities and higher outcome magnitudes and a relative underweighting of high probabilities and smaller outcome magnitudes.

As an illustrative example, agents often prefer to forego high probability low to moderate magnitude gains in pursuit of large, but remote upside payoffs; they are willing to gamble in giving up some certain positive outcome for a chance at significantly larger upside. Agents are also very often willing to take on a high probability, high magnitude risk so that they may have some chance to avoid a certain cost. In exchange for taking on such risk, agents expect a return, defined as;

$$\text{Expected Payoff From Risk} = PTB_R \{w^{(+)}(p_{U\,i\,t}), v^{(+)}(P_{U\,i\,t})\}$$

Risk and speculation have very precise and different meanings within Psychological Economics Theory. As defined above, risk is the expected impact of the uncertain potential downside, the uncertain component of personal total cost. Speculation is defined when the agent deliberately takes on risk in pursuit of payoff from that risk, expecting both reward and risk possibilities in excess of the certain part of personal total cost and personal total benefit.

Theorem – Speculation
Speculation is defined when an agent deliberately takes on risk in pursuit of payoff from that risk, expecting both reward and risk possibilities in excess of the certain part of personal total cost and personal total benefit, with reward from risk exceeding risk taken.

$$PTB_R \{w^{(+)}(p_{U\,i\,t}), v^{(+)}(P_{U\,i\,t})\} > PTC_R \{w^{(-)}(q_{U\,i\,t}), v^{(-)}(Q_{U\,i\,t})\} > 0$$

2.5 Psychological Grounding of the Trade-Off Constraint

Many psychological principles that have been experimentally established serve to provide scientific evidence of the existence of the psychological trade-off curve. *Cognitive Dissonance* is a vital reason that the psychological trade-off curve exists. The concept is characterized by agents maintaining a particular belief that has been held for a long time, even when it is at odds with new evidence (Festinger, 1957). This behaviour reflects the fact that agents trust what they have learned over their lifetime of experience, as opposed to a single observation, in determining expected personal total cost and personal total benefit. Experiences are anchored through repetition and as they are built up over time they become more certain to the decision-maker. Each agent's psychological trade-off curve incorporates the expected impact of cumulative counter agent effects, giving short-to-intermediate-term permanence to the curve.

Closely related to the concept of cognitive dissonance is that of *status quo bias*. Experiments show (Kahneman et al., 1991) that agents will typically not change an established behaviour unless the incentive to change is significant. The particular experiments noted specifically tied this back to the principles of loss aversion and endowment, being essentially an observation that any outcome other than the status quo is most likely under normal circumstances to represent heightened uncertainty and increased exposure to personal total cost, at least in the short-term. As discussed previously, this necessary 'front-loading' of personal total cost with eventual resulting personal total benefit is captured in the return on cumulative effort corollary of the cumulative counter agent effects principle. When an agent perceives that doing nothing is likely to lead to drastically negative outcomes, conditions for change are in place.

The psychological concept of *compartmentalizing* not only serves to ground the axiom of matched outcomes, but combined with the psychological principle of *distinction bias*, also helps underpin transitive, rank dependent preferences. Distinction bias is the tendency to view two options as more dissimilar when they are evaluated

simultaneously rather than separately, which also allows agents to make the ordinal category rankings that underpin their preference ranking. Distinction bias drives agents to make distinctions, because alternatives are being evaluated side-by-side (Hsee & Leclerc, 1998). This supports a well-defined preference ordering, defined across overall weighted outcome values (events) relative to other possible events. The combination of compartmentalizing and distinction bias also provides strong psychological grounding for use of the sign-comonotonic trade-off consistency criterion which essentially replaces the Expected Utility independence axiom in Cumulative Prospect Theory. A thorough axiomatization of sign-comonotonic trade-off consistency has been provided by Wakker & Tversky (Wakker & Tversky, 1993).

Cumulative Prospect Theory posits that decisions are weighed as gains or losses relative to the status quo scenario. Psychological Economics Theory does not absolutely require this condition, as the selection of a benchmarking point is a subjective decision personal to each agent. Many agents will relate outcomes to the current status quo, whereas many others will relate to zero and still other highly motivated and proactive agents will reference against some target scenario they see resulting in the future as the result of their continued action. A number of related psychological principles give further weight to the resilience of the psychological trade-off curve as a realistic representation of decision-making optimization. The framing concepts of *selective perception* and *confirmation bias* (Tversky & Kahneman, 1981) in particular have the effect of anchoring and perpetuating the trade-off curve relationship as an agent makes more and more decisions over time.

Selective perception is well documented in psychology and results in a tendency of the expectations of agents to actually affect their perception of potential outcomes. In essence, this implies that the trade-off relationship agents possess is applied to new situations, making it in many ways ‘self-fulfilling’. This behavioural driver is further strengthened by the existence of confirmation bias, which psychological research demonstrates has the effect that agents actually search for and interpret information in a manner that confirms their existing preconceptions. Agents in effect frame their perspective, reflected through their perceptions of personal total cost and personal total benefit, which further perpetuates through projection onto future decision scenarios.

Longer time horizons are a major driver of increased levels of uncertainty, because they can introduce many new impacts, potentially even requiring a reset of an agent's preference rankings. *Hyperbolic discounting* is a psychological principle, which succinctly captures the impact of various time horizons, due to changing risk profiles and preference. The principle notes that an individual will have a stronger preference for more immediate payoffs relative to later payoffs (Green et al., 1994). In addition, this preference itself accelerates as all payoffs are closer to the present. The psychological concept of *recency* must also be considered (Miller & Campbell, 1959). It confers that agents place the greatest emphasis on more recent information and either ignore or forget to consider distant information. This psychological principle has a major potential impact on decisions within Psychological Economics Theory, because it means that agents may apply a particular local maximum personal total cost threshold (PTCT) in the short-term and then revisit their decision with a different maximum PTCT in the longer term.

To illustrate the importance of the psychological personal total cost versus personal total benefit constraint concept, consider an example. By ridding oneself of a fear of heights, an agent could presumably instantly increase utility, by enjoying height-related activities without discomfort. Given a very minute actual risk of death in most situations, an agent's fear of heights is in general taking potential personal total benefit 'off the table'. This is where a psychological understanding of behaviour better grounds the economic model of utility maximization and decision-making. Agents can change their associations over time, but a lifetime of experience and conditioning makes this beyond the scope of a single economic decision at hand. It is this grounding of economic optimization in psychological principles that enhances the traditional economic model and leads us to a robust understanding of behaviour by way of Psychological Economics Theory.

The psychological trade-off constraint is first and foremost grounded as a psychological and microeconomic tool, and is very powerful in explaining the unique decision-making behaviour of individual agents, since agents may associate vastly different personal total cost and personal total benefit to the potential outcomes of decisions and states of the world at any given point in time. Considering once again the agent that is scared of heights, he or she associates massive personal total cost to hand gliding, versus another individual who associates massive personal total benefit to it. Each agent clearly possesses an opposing association of personal total cost versus personal total benefit attached to the decision of whether or not to hand glide.

The PTC versus PTB trade-off is further supported by observations of neurobiology. The Somatic-Marker hypothesis (Damasio et al., 1991) asserts that within the context of uncertainty, when considering potential future outcomes, agents simplify their decision-making process with the aid of emotions (in the form of bodily states). These bodily states distinguish alternative decisions/actions as being advantageous (i.e. delivering overall personal total benefit) or disadvantageous (i.e. delivering overall personal total cost). This neurobiological survival mechanism, underpinning instinctual rationality and emotional rationality, motivates agents to be cautious and incrementally learn, advancing at a managed level of risk. The Somatic-Marker hypothesis provides a strong neurological underpinning for the psychological concept of compartmentalization as discussed previously.

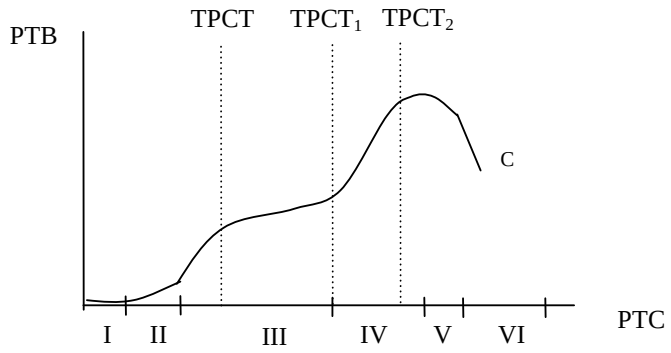
2.6 A Time Profile of the Psychological Trade-off Curve

The numerous psychological drivers discussed previously net out to result in a generalized form of the psychological trade-off constraint with six fundamental phases that occur over the time frame relevant to a significant decision. Each phase is defined by changes in the first and second derivatives of the trade-off curve, c. This is a generalized modeling typical of many observed situations in practice and is mostly representative of significant decisions with multi-period relevance. It reflects the impact of economy/society-wide status quo inertia via cumulative counter agent effects, whereby agents typically can only make gradual progress over time toward the goals they have decided to reach, as they interact within the context of competing agents.

The full range of phases of significant decision-making over time is:

Phase I	(Survival):	$c' > 0$ and $c'' < 0$
Phase II	(Low-Hanging-Fruit):	$c' > 0$ and $c'' > 0$
Phase III	(Plateau):	$c' > 0$ and $c'' < 0$
Phase IV	(Rapid Pay-off):	$c' > 0$ and $c'' > 0$
	(Peak):	$c' = 0$ and $c'' < 0$
Phase V	(Diminishing Results):	$c' < 0$ and $c'' < 0$
Phase VI	(Rapidly Diminishing Results):	$c' < 0$ and $c'' > 0$

Figure 4: *Phases of the typical psychological trade-off constraint over time*



Phase I: 'Survival'

Not typically a significant phase in the majority of decisions facing agents in developed economies, this can be the key phase facing agents in situations of poverty. With minimal prospects for personal total benefit, agents facing dire circumstances are willing to put in significant effort and endure extensive personal total cost to obtain some minimal amount of personal total benefit; the basics of life, such as food and shelter. As a result, in Phase I, $c' > 0$ and $c'' < 0$. Agents are relatively *PTC aggressive* and variability seeking at this stage.

Phase II: 'Low-Hanging Fruit'

The steep slope at this lower end of the psychological trade-off constraint curve captures the fact that individuals can usually obtain early results from what is known in popular culture as 'low-hanging-fruit'. By focusing and prioritizing, early results can be achieved without a great deal of sacrifice. This is modeled via the conditions $c' > 0$ and $c'' > 0$. Agents are relatively *PTC averse* and risk averse at this stage.

Phase III: 'Plateau'

At the Plateau phase, each additional unit of potential personal total cost taken on (including certain and uncertain components) will typically yield small amounts of potential personal total benefit. At this point conditions are $c' > 0$ and $c'' < 0$. This is the phase over which significant 'up-front' effort becomes required by the agent in order to continue down the path of actions and subsequent decisions associated with a particular decision in pursuit of continued benefit. Each unit of additional effort (personal total cost) is taken on for additional contemporaneous

personal total benefit of a generally smaller amount. There is anticipation of greater results in the future, which require even further effort (personal total cost), which in turn motivates the individual to endure the temporarily diminishing returns. Agents are again relatively PTC aggressive and variability seeking at this stage.

Phase IV: 'Rapid Payoff'

During this phase the extensive up-front effort made during the plateau phase is beginning to pay off. Learning has occurred, infrastructure is in place, and as a result, each marginal unit of effort (personal total cost) delivers a strong personal total benefit. Significant PTB typically occurs at this stage as a result of effort expended in previous stages. Conditions become $c' > 0$ and $c'' > 0$. During this phase, abundance and wealth accumulate and there is clear motivation to uphold the decision and to continue pursuing the actions associated with the decision. Agents are relatively PTC averse and risk averse at this stage.

Phase V: 'Diminishing Results'

Efforts in life don't deliver unrelenting personal total benefit forever and instead peak at some point as a result of direct physical world constraints and through cumulative counter agent effects. This phase demonstrates ongoing diminishing sensitivity to personal total benefit, via values of $c' < 0$ and $c'' < 0$. Agents realize the comfort gained through abundance and demonstrate diminishing sensitivity to more personal total benefit. The result is typically that the agent is motivated to take on much smaller amounts of risk/personal total cost for each potential unit of personal total benefit. There is little need to take on the heightened risk associated with increasingly uncertain situations. This is the phase in which inertia sets in on decision-making and where the status quo begins to perpetuate. Agents are relatively PTC averse and risk averse at this stage of the decision cycle.

Phase VI: 'Rapidly Diminishing Results'

This is the phase in which each additional unit of personal total cost taken on actually decreases personal total cost at an increasing rate, like a pro athlete that is significantly past his/her prime. During this phase $c' < 0$ and $c'' > 0$ and agents are relatively PTC averse and risk averse.

2.7 Optimization

Agents make a decision, λ, by selecting the alternative mindset, course of action or course of inaction that yields the associated highest subjectively valued prospect:

$$\lambda = \text{Max } V(f)$$

In making a decision an agent chooses a prospect over all values of *i* and *t*, to bear a particular certain impact $v^{(-)}(Q_{Ait})$, $v^{(+)}(P_{Ait})$ and an uncertain potential impact through $w^{(+)}(p_{Uit})$, $v^{(+)}(P_{Uit})$, $w^{(-)}(q_{Uit})$ and $v^{(-)}(Q_{Uit})$. We therefore recognize λ as a conditional judgement, such that:

$$\lambda = \{ w^{(+)}(p_{Uit}), v^{(+)}(P_{Uit}), w^{(-)}(q_{Uit}), v^{(-)}(Q_{Uit}) \mid v^{(-)}(Q_{Ait}), v^{(+)}(P_{Ait}) \}$$

The optimization process in Psychological Economics Theory is therefore a maximization of;

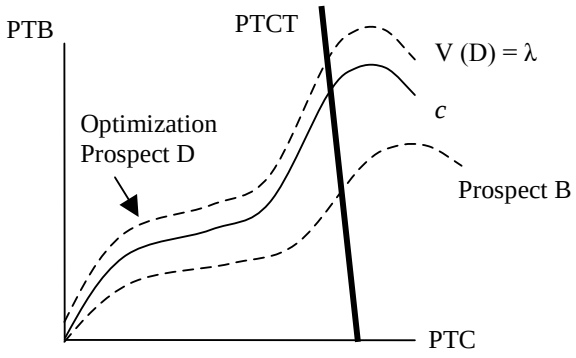
$$V(f) = V\{w^{+(+)}(p_{Uit}), v^{+(+)}(P_{Uit}), v^{+(+)}(P_{Ait}), w^{+(-)}(q_{Uit}), v^{+(-)}(Q_{Uit}), v^{+(-)}(Q_{Ait}), \Psi^{+}_{i}, w^{-(+)}(p_{Uit}), v^{-(+)}(P_{Uit}), v^{-(+)}(P_{Ait}), w^{-(-)}(q_{Uit}), v^{-(-)}(Q_{Uit}), v^{-(-)}(Q_{Ait}), \Psi^{-}_{i}\}$$

Subject to,

$$c: [PTC^{C}\{w^{(-)}(q^{C}_{Uit}), v^{(-)}(Q^{C}_{Uit}), v^{(-)}(Q^{C}_{Ait})\}, \Psi^{C}_{i}] \rightarrow [PTB^{C}\{w^{(+)}(p^{C}_{Uit}), v^{(+)}(P^{C}_{Ait}), v^{(+)}(P^{C}_{Uit})\}] \text{ and}$$

$$\text{Max}[\ PTC^{C}\{w^{(-)}(q^{C}_{Uit}), v^{(-)}(Q^{C}_{Uit}), v^{(-)}(Q^{C}_{Ait})\}, \Psi^{C}_{i}\ ] = PTCT$$

Figure 5: *Graphical Representation of Target Decision: The 'Leaning X'*



Only prospects that are at all points on or above the trade-off curve, *c*, will be considered, such that a selected maximum personal total cost threshold, PTCT, is not exceeded. It is important to always consider the status quo, or

inaction, as an alternative to be weighed against other potential decision alternatives. The status quo will have its own associated personal total cost and personal total benefit values for the agent.

Of additional importance is the reality that decision-making occurs a priori to observed outcomes. Potential personal total benefits and personal total costs are therefore anticipated as best as possible. Decisions are impacted by previous decisions and observed outcomes. Decisions most often require associated follow-through actions and subsequent reaffirming decisions to deliver meaningful results. For example, the decision to lose weight is actually a sequence of related decisions, as an agent must decide each and every day what to eat and how much to exercise.

Many agents will also routinely underestimate personal total costs, based on overconfidence, and find themselves revaluating once action has been taken and results observed. This captures the notion of 'second guessing', and contributes to iterative decision-making, which will be discussed subsequently. The 'Leaning X' diagram demonstrates the optimization process of an agent in making a decision and in selecting a course of action, but it does not represent an equilibrium. The subsequent section will explore the concept of *testing*, demonstrating that equilibrium cannot result in any decision-making environment because uncertainty is greater than zero.

2.8 All Information Relevant to Decision-Making is Transitory & Endogenous

2.8.1 Complete Transitory Endogeneity

In the face of uncertainty greater than zero Psychological Economics Theory implies that all 'information' that can have material impact to an agent's decision is subjective and endogenous, revealed only through actual transactions or through bid/offer behaviour.

Theorem – Complete Transitory Endogeneity
All information relevant to decision-making is endogenous as it is subjectively interpreted and borne into the decision-making process by an agent based on perceived personal total cost and personal total benefit implications. If known information has not been interpreted by a decision-making agent and applied to a particular decision, then by definition, it has not been taken as applicable to the decision at hand, based on that agent's interpretation. The major implication is that economic information does not necessarily converge to exogenous values or 'natural' values, and can cumulatively build upon prior endogenous values, resulting in trending.

This is not equivalent to a constrained information equilibrium, in the sense of either strong or weak form rational expectations, since these approaches suggest that agents maximize utility subject to exogenous information.

Psychological Economics Theory postulates that information itself is only created by agents as they interpret past and present experience, forming their own interpretation of it, and when they form expectations of future outcomes based on this. Information is revealed endogenously by agents when they suspect that it is advantageous for them to do so. Individuals can interpret exogenous factors in a vastly different manner from each other. Just as no two people look exactly the same, no two interpretations by agents are the same. Decision-making is by definition an activity of individual agents and hence all initially exogenous information is interpreted and applied by agents, becoming endogenous. This is a fundamental distinction, because as information is interpreted by agents it is applied to transactions/negotiations to the extent that it is to the agent's advantage, in terms of PTB and PTC, meaning that a large portion of information may be held back.

A fundamental implication of the realization that all economic/social information is endogenous to the decision-making process is that it is only revealed by agents through the bids of demanders, the offers of suppliers, past actual transactions and various other non-price signals. Since agents must make decisions in the face of uncertainty, a priori, they commonly find themselves iteratively re-evaluating and making new decisions as actual transactions occur or based on significant new signals of other agents. Agents form their perspective based on past experience, adapting their expectations as necessary, through the biological and psychological process of learning. After each transaction, agents will process new information and a new 'Leaning X' optimization diagram may apply, guiding potentially revised decisions and actions. Even if new information does not come into consideration, most significant decisions will require sustained effort to implement and hence further reaffirming decisions to see them through. The status quo action or inaction can also become an attractive alternative with immediate payoff.

2.8.2 Testing Behaviour

A special type of iterative decision-making, denoted as *testing behaviour*, is a fundamental result within Psychological Economics Theory. In fact, testing behaviour can be established in any model whenever uncertainly is greater than zero. In mainstream models *testing behaviour* can be expected to result as agents seek to determine whether they can gain further by discovering the exogenous information they do not currently have, as a result of a constrained information set. In Psychological Economics Theory testing behaviour becomes far more prominent and has major theoretical implications.

Since agents cannot know with certainty the PTB versus PTC trade-off functions of other agents, they cannot know the future decisions or actions of individuals with whom they may potentially interact. There will in effect be some positive level of uncertainty, which means that $w^{(-)}(q_{Uit}) > 0$ and $w^{(+)}(p_{Uit}) > 0$. Every agent faces the dilemma of not knowing whether the status quo or a particular different action into the uncertain will yield greater personal total benefit net of personal total cost. Even when an agent undertakes his or her best guess as to the personal total benefit and personal total cost outcomes of a particular decision, they know they are only making a best guess, with uncertainty, and with some level of risk remaining.

As a result, each agent will *test*, which means that in the face of outcomes with uncertainty they will 'put their toe in the water' to a degree of comfort in line with their risk tolerance and overall PTC tolerance. They will take on some small level of known personal total cost $\{ v^{(-)}(Q_{Ait}) \}$ and known personal total benefit $\{ v^{(+)}(P_{Ait}) \}$ and risk $\{ w^{(-)}(q_{Uit}), v^{(-)}(Q_{Uit}) \}$ to see whether new information gained from the resulting event of that decision/action produces new expectations of higher PTB relative to PTC in the future.

In any situation where agents are not infinitely provided for by others at no cost, each agent must make decisions and take actions to survive and obtain satisfaction/utility. Whenever there is a clear indication that expected reward from risk exceeds expected risk, decision-making becomes relatively easier, but when levels of uncertainty are high and expectations exist only with a wide variance, agents face a much more difficult scenario. In such situations they can only obtain further insight by exposing themselves to heightened risk in a measured 'testing' fashion, attempting to uncover relatively larger upside. Agents always bear uncertainty, and so no matter how risk averse, they will have some level of acceptable uncertain personal total cost less than PTCT that they are willing to take on in order to test. As an agent becomes more risk averse, PTCT approaches zero as risk aversion approaches ∞. The Testing Behaviour theorem can be formally stated as:

Theorem – Testing Behaviour
Whenever risk is perceived to exist, i.e. $w^{(-)}(q_{Uit}) > 0$, testing will occur as agents will take on a small amount of additional risk $\{ v^{(-)}(Q_{Uit}) < \epsilon_Q, w^{(-)}(q_{Uit}) < \epsilon_q \}$ in addition to certain personal cost $v^{(-)}(Q_{Ait})$ and certain personal benefit $v^{(+)}(P_{Ait})$ in order to see whether they can obtain additional uncertain personal total benefit (reward from risk) $\{ v^{(+)}(P_{Uit}), w^{(+)}(p_{Uit}) \}$, as long as $c' > 1$ and such that PTC $\{ w^{(-)}(q_{Uit}), v^{(-)}(Q_{Uit}), v^{(-)}(Q_{Ait}) \} <$ PTCT. Testing behaviour is the underlying core of speculation.

This is a vital dynamic of Give-and-Take Decision Theory and directly produces two of the distinguishing theoretical outcomes of the model – an oscillating trend and reversal market clearing dynamic and a prediction that neither static nor steady state equilibriums can exist. These will be discussed in depth in the second core article of Psychological Economics Theory, to which our attention will now turn in order to model interaction between agents, given that we have here established foundations and an overview of the complete theory and specified a framework of individual choice.

3. Bibliography

Abdellaoui, M et.al. (2010). *The Rich Domain of Uncertainty*. American Economic Review.

Black, D. (1958, 1987). *The Theory of Committees and Elections*. Boston: Kulwer.

Chateauneuf, A & Wakker, P. (1999). *An Axiomatization of Cumulative Prospect Theory for Decision under Risk.* Journal of Risk and Uncertainty.

Chew, S. & MacCrimmon, K. (1979). *Alpha-Nu Choice Theory: A Generalization of Expected Utility Theory*. British Columbia: University of British Columbia.

Choquet, G. (1955). *Theory of Capacities.* Grenoble: Ann. Inst. Fourier.

Damasio, A.R., Tranel, D. & Damasio, H. (1991). *Somatic Markers and the Guidance of Behaviour: Theory and Preliminary Testing*. In H.S. Levin, H.M. Eisenberg & A.L. Benton (Eds.). *Frontal Lobe Function and Dysfunction.* New York: Oxford University Press.

Dolan, E et.al. (1976). *The Foundations of Modern Austrian Economics*. Kansas City: Sheed & Ward.

Eatwell J., Milgate. M. & Newman, P. (1987 and 1991). *The New Palgrave: The World of Economics*. New York: W.W Norton and Company.

Elster, J. (1989). *Nuts and Bolts for the Social Sciences*. United Kingdom: Cambridge University Press.

Fennema, H & Wakker, P. (1997). *Original and Cumulative Prospect Theory: A Discussion of Empirical Differences.* Journal of Behavioral Decision Making, Vol. 10.

Festinger, L. (1957). *A Theory of Cognitive Dissonance.* Stanford, CA: Stanford University Press.

Friedman, M. (1953). *Essays in Positive Economics.* Chicago: University of Chicago Press.

Green, L., Fry, A.F., & Myerson, J. (1994). *Discounting of Delayed Rewards: A Life Span Comparison.* Psychological Science.

Hansson, Sven Ove. (1994). *Decision Theory: A Brief Introduction.* Stockholm: Department of Philosophy and the History of Technology, Royal Institute of Technology (KTH).

Hayek, F. (1951). *Price Expectations, Monetary Disturbances and Malinvestments.* In *Readings in Business Cycle Theory.* Homewood, Ill.: Irwin.

Hayek F. (1928 [1984]). *Intertemporal Price Equilibrium and Movements in the Value of Money.* In McCloughry, R. (ed.) (1984), *Money Capital & Fluctuations*. London: Routledge.

Hirshleifer, J. (1985). *The Expanding Domain of Economics.* American Economic Review.

Horton, A. (1995). *Intertemporal Substitution Decisions and Aggregate Economic Fluctuation.* London, Ontario. Working Paper, University of Western Ontario.

Howitt, P. (1990). *The Keynesian Recovery and Other Essays*. New York: Phillip Allan.

Hsee, C.K., & Leclerc, F. (1998). *Will Products Look More Attractive When Presented Separately or Together?* The Journal of Consumer Research.

Kahneman, D., Knetsch, J. L. & Thaler, R. H. (1991). *Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias.* Journal of Economic Perspectives.

Kirzner, I. (1976). *Equilibrium versus Market Process* in *The Foundations of Modern Austrian Economics.* Kansas City: Sheed & Ward.

Kirzner, I. (1997). *Entrepreneurial Discovery and the Competitive Market Process: An Austrian Approach.* Journal of Economic Literature.

Langlois, Richard N. (1986). *The Market As An Economic Process: Ludwig M. Lachmann.* Oxford: Basil Blackwell.

Laidler, D. (1991). *The Golden Age of the Quantity Theory; The Development of Neo-Classical Economics 1870-1914*. London, Canada. Monograph.

Leijonhufvud A. (1981). *Information and Coordination*. Oxford: Oxford University Press.

Lewandowski, M. (2007). *Is Cumulative Prospect Theory a Serious Alternative to the Expected Utility Paradigm?* Florence, Italy: Economics Department, European University Institute.

List, J. (2004). *Neoclassical Theory Versus Prospect Theory: Evidence from the Marketplace.* Framed Field Experiments 0047, The Field Experiments Website.

Lucas, R. (1972). *Expectations and the Neutrality of Money*. Journal of Economic Theory.

Miller, N. & Campbell, D. T. (1959). *Recency and Primacy In Persuasion as a Function of the Timing of Speeches and Measurements*. Journal of Abnormal and Social Psychology.

Nash, J. (1950). *Equilibrium Points in N-Person Games*. Washington, DC: Proceedings of the National Academy of Sciences.

Parkin, M. & Bade, R. (1992). *Modern Macroeconomics*. 3rd. ed. New Jersey: Prentice-Hall.

Patinkin, D. (1989). *Money, Interest and Prices, 2nd ed. Abridged*. Massachusetts: The MIT Press.

Quiggin, J. A. (1982). *Theory of Anticipated Utility.* Journal of Economic Behavior & Organization.

Rothbard, M. (1976). *Praxeology: The Methodology of Austrian Economics.* In *Foundations of Modern Austrian Economics.* Kansas City: Sheed & Ward.

Scott, J. (1995). *Sociological Theory: Contemporary Debates*. Cheltenham: Edward Elgar.

Sargent, T. J. (1987). *Rational Expectations.* In *The New Palgrave: A Dictionary of Economics*. Basingstoke, UK: Palgrave MacMillan.

Tuthill, J., & Frechette, D. (2002). *Non-Expected Utility Theories: Weighted Expected, Rank Dependent, and Cumulative Prospect Theory Utility*. St. Louis: MO: Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management.

Tversky, A. & Kahneman, D. (1979). *Prospect Theory: An Analysis of Decision under Risk.* Econometrica, 47(2).

Tversky, A. & Kahneman, D. (1981). *The Framing of Decisions and The Psychology of Choice*. Science.

Tversky, A. & Kahneman, D. (1992). *Advances in Prospect Theory: Cumulative Representation of Uncertainty.* Journal of Risk and Uncertainty.

Tversky, A., & Kahneman, D. (2004). *Advances in Prospect Theory: Cumulative Representation of Uncertainty*. Presentation Notes.

von Mises von, L. (1953). *The Theory of Money and Credit*. New Haven: Yale Press.

von Neumann, J., & Morgenstern, O. (1944, 1947, 1953). *Theory of Games and Economic Behavior*. New Jersey: Princeton University Press.

Wakker, P., Erev, I. & Weber, E. (1994). *Comonotonic Independence: The Critical Test between Classical and Rank-Dependent Utility Theories.* Journal of Risk and Uncertainty.

Wakker, P., & Tversky, A. (1993). *An Axiomatization of Cumulative Prospect Theory*. Journal of Risk and Uncertainty

Walker, D. (ed). (1984). *Money and Markets: Essays by R.W. Clower.* Cambridge: Cambridge Press.