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INSTANT UTILITY APPROACH TO THE SOCIAL SCIENCES

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"Given that the only certain fact is the intensity of pleasure felt at an instant of time, the only epistemologically sound approach is to take intensity as the primary concept." Georgescu-Roegen, in his introduction to the English translation of Hermann Gossen's book on behavioral theory ([1854] 1983, lxxxi).

ABSTRACT

It is of course true of science that deeper theory opens new vistas, and economics may now justifiably advance to a more essential paradigm. The basis for this deeper theory is empirical (cardinal and measurable) instant utility (feeling state, Dolan [2002])—the time derivative of utility (satisfaction). Immediate benefits could include: Reconciling sociology and economics (both could now agree that wants, desires, satisfactions, etc. are endogenous); more correct modeling of time and (periodic) human activity in microeconomics; modeling macroeconomic equilibrium-states as a locus of dynamic states; and the substantive modeling of bounded rationality, including uncertainty and expected risk. Because socioeconomic theory could now be derived from deeper instant utility theory, the several branches may be unified in an overarching classification. As a demonstration herein, Real Business Cycle Theory and Equilibrium Theory are connected or related by a sequence of definitional assumptions on the basis of instant-utility theory (the Gossen Equation). Then, after presenting the mathematical formulation of instant-utility theory, Ramsey's rule for saving is extended to account for expected-risk and autonomic discounting. Finally, the prospect for greater cooperation between sociology and economics is addressed. …It may be emphasized that much of the important and far-reaching progress in economics and social psychology over the past 100+ years is naturally accommodated by the instant-utility theory. This progress includes the rationality assumption, diminishing marginal rates of substitution, the theory of the firm in economics; and social-identity theory in social psychology. Furthermore the historical bases for finite interest rates—time preference, better times ahead, shortness of life, increasing technological knowledge, diminishing vitality in later years, and risk—may be substantively formulated.

This paper, originally completed in July 2003 and briefly refined for SSRN upload in 2004, is unchanged herein except for clarifying refinements of (non-mathematical) text. However, it should be noted that a recent paper—"Fully Temporal System Linking Productivity to Risk and Yielding Completed Input/Output Substitution." (2011; (Available on the Social Science Research Network: http://ssrn.com/author=381224.)—has integrated neoclassical and Gossenian utility theory, and unified or joined the corresponding (previously separate) economic systems.

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1.0 INTRODUCTION

For over a century, the science of economics, with its important and far reaching advances, has been separated from sociology at a most fundamental level—how human values are defined (Baron and Hannan, 1994). In the real economic world, the values an individual assigns to consumables (and things generally, of every kind) are determined by his or her personal psychosomatic attributes and context, in accordance with the operative plan (which continually evolves with expected new information, and discontinuously changes with unexpected information). Sociologists, and institutional economists, recognize this *endogenous* dimension of human valuation of all things important. But micro-economists of the mainstream *neoclassical-equilibrium* genre over-ride this natural systemic etiology by assigning human satisfaction (utility) directly to consumables.[1]

For the same reason, the methodology of mathematical micro-economics is distinct or separate from the methodology of natural science (mathematical physics, in particular).[2] More to the point, economics is separate in its epistemology and (hence) methodology by not extending deeply to the empirical behavioral (neuropsychological) foundation [see also Hausman 1992, and Georgescu-Roegen's introduction to Gossen's book (1983)].

Here an important question may be offered—should mathematical micro-economics seek a deeper foundation, and thereby bring about or advance a consilience with social and natural science? Were we to seek this deeper level, an elementary yet important step must (I believe) be taken—In particular, human satisfaction (utility) [or, more essentially, instant utility or "feeling state" (Dolan [2000])]—should be identified <u>primarily and exclusively</u> in <u>basic</u> theory with <u>all</u> (mental and physical) human activity-duration, productive and consumptive, rather than (prematurely, or "too soon") with commodities.

[1] Medicines, as an example, are taken for their expected (intertemporal) benefits—where the beneficial experience can occur almost immediately or be delayed weeks or years into the future.. The rigorous methodology would be to recognize (at least as a matter of principle) the "benefit later" character of the products (indeed, all products) and *impute* expected-experience utility to its value-in-exchange. Instead, as noted in the text, this real-world process is short-circuited by the direct assignment of utility to consumables. Correction of this error would significantly advance time as a realistic and powerful concept in economic theory.

[2] In my reading, the dichotomy between the two methodologies (as examples: (1) unlike mathematical physics microeconomics is not empirically "grounded"; and (2) mathematical economics tolerates dimensional inconsistency, while such is absolutely prohibited in basic and applied physics) has never

The distinguishing feature of the proposed methodology is the role of instant utility in human behavior. In this regard, instant utility is an empirically measurable parameter (Rolls 1975) that is connected to human *economic* activity—production, consumption, and rest. It is the fatigue we feel towards the end of a long day at work; the enjoyment we experience while driving an automobile earned by our labor; and the pleasure of relaxation (leisure and rest, which frequently, if not always, involves consumption of resources). Because instant utility is the time-derivative of utility—i.e., a constituent or component thereof—it may accordingly be concluded that the property resides at a more fundamental level.

An analogy may help establish the value of a rigorous and coherent methodology of economics, one built on an epistemologically sound foundation. In this analogy, each of us can imagine working on a scaffolding, or framework, high above the street. If we know the scaffolding is of sound foundation and construction we would confidently climb, and work, at the higher levels. But if the ground under the scaffolding is not solid, and the framework is irregular and inconsistent, we would, with good reason, refuse to climb very high.

Standard economics is something like this. It has been observed that economists do not predict "out of sample (Aaron 1994, p. 11)." That is, theory is applied within the confines of empirical data, and extrapolated little if any beyond this data. In physics, prediction out-of-sample is, of course, routine. One need only think of the principal formulas of physics to realize this—for examples, $E=MC^2$, $F=MA$, $E=IR$, etc. But mainstream microeconomics has not yet settled on its substantive foundation. Furthermore, because microeconomics takes important but nonessential utility to be preeminent, its methodology, largely based on direct commodity-utility assignment, is in a sense "suspended" or "floating above" the substantive foundation. One consequence is a level of rigor well below that of mathematical physics and engineering. Accordingly, just as the construction worker refuses to climb an unsound scaffolding, the economist refuses, and properly so, to predict out of sample.

On its face, the small step to instant utility as fundamental should not be controversial. Instant utility has been a significant part of economic theory since the nineteenth century, and

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been substantively addressed in the literature—although there has, of course, been considerable criticism of standard microeconomics over the decades.

prominent economists have determined that instant utility is more basic than commodity utility. (Leon Walras may be included in this group [1895]. In more modern times Nicholas Georgescu-Roegen advocated the approach—see, for example, his introduction to Gossen's book [1854] 1983). The step, however, challenges standard microeconomics—and this can bring controversy. The problem is that microeconomics does not model human behavior as consisting of discrete or separate activities, each with corresponding instant-utility, placed end-to-end (as, for example, an individual who first works to produce a tool, then uses the tool to produce food, consumes the food, and finally rests, thereby completing a 24 hour day).

Methodologically rejected (indeed, *epistemologically* rejected [!]) by standard microeconomic theory is the existence of consumptive activity (or "duration-for-consumption") alongside (the long recognized and modeled) duration-for-labor in the individual's daily activity-regimen. The reason is the pre-eminence of direct-assignment of consumable utility, which immediately sets aside duration-for-consumption (in order to avoid utility double counting). Much of standard mathematical economics is based on this premise—hence its *keystone* character, and unyielding longevity throughout the twentieth century to the present time.

It is important to emphasize that this more fundamental approach is not a sweeping overthrow of mainstream economic theory. Of course there are the inevitable adjustments—the valuable substance of scientific advance. As two particulars: (1) Instant utility theory consigns the essential postulates of core (equilibrium) economics (e.g., rationality, consumerism, and diminishing marginal rates of substitution) to simplifying assumptions. The assumptions are still important and germane, but now serve to simplify mathematical economic behavior starting from the comprehensive behavioral foundation (Gossen equation)—much as the mathematical aerodynamics of flight are simplified by the assumptions of calorically perfect gases, perfect-gas equation of state, and inviscid flow (e.g., in the Bernoulli equation and Navier Stokes equations). And (2): utility is (re)established as cardinal—where utility is the time-integral of instant utility (time and instant-utility both measurable) in the Gossen equation. (This challenges neoclassical Equilibrium Theory, which is falsely based on utility as an ephemeral or transcendent or <u>analytically irrelevant</u> entity.)

Neoclassical assumptions (with qualifications) would continue to play an indispensable role in analysis—indeed, without appropriate assumptions, the practical business of analysis, in the natural sciences as well as social sciences, would not be possible. Two things are needed: (1) a basic and coherent foundation; and (2) meaningful simplifying assumptions consistent with this foundation. It is a central purpose of the present contribution to discuss how this can be done.

An important contribution to the formulation of human behavior was made by Hermann Gossen (1854), a scholar virtually unknown in his time. Leon Walras, one of the founders of neoclassical equilibrium theory, learned of Gossen's book after publishing his own great work (1874-77)—too late to influence his creative process (Walras 1885). He granted credit to Gossen for discovering the principles of utility theory, and appeared to recognize years later that Gossen's instant utility was more fundamental than his commodity utility (1895).[3] But the die had been cast for equilibrium theory as the core of standard economics.

While many of the attributes of the present theory (mainly in application) have their basis in neoclassical theory, the Austrian Tradition more closely represents the spirit of the human-activity approach in microeconomics:

> "[The Austrian] perspective is that which particularly emphasizes: The purposefulness of individual action; the role of knowledge in economic choice; the subjectivity of the phenomena that interest economists; and the *ex ante* role in which time affects activity." (Kirzner 1981)

Shackle contributed his perspective by recognizing the *psychosomatic* basis for the self-direction of activity (1958), an insight that was later given empirical support by Damasio (1994); Bechara, et. al. (1997); Damasio (1999; See also Metzinger 1999.); and Price (2000). In very recent years, a rapid pace of discoveries in neuropsychology is giving credence to the subjective approach—regarding expectation, discounting, memory, subliminal intention, planning, etc.—and further establishes the mind-body connection that allows mathematical treatment.[4]

It may accordingly be understood that the broad scope of economics is ready or positioned for a new and deeper formulation. In this view, economics is related to psychology as fluid mechanics, for example, is related to physics. In either case, advantageous assumptions—human rationality in economics being analogous to continuum gases in fluid mechanics—permit

[3] In recognition of Hermann Gossen's essential contributions to the instant-utility approach, the emotive equation has been renamed the *Gossen equation* in my work.

a scope and depth of study that would not otherwise be possible. In the following pages the mathematical formulation of behavior is presented, followed by its application to selected problems in economics and reference to developments in sociology.

2.0 MATHEMATICAL FORMULATION AND EPISTEMOLOGY

In formulating human behavior it does appear necessary to begin with essential empiricism. Instant utility—pleasure/pain in everyday language (or, in neuropsychology, "feeling-state")—is a fundamental concept in mathematical behavior[5,6]. Instant utility has been measured during brain surgery with the aid of the volunteer-patients (Rolls 1975). In particular, electrical stimulation of specific regions of the brain has produced pleasurable sensations in patients. The reverse is also true, where patients engaged in pleasurable activities have produced finite electrical potentials on the micro-probes. The important immediate point is that instant utility is *measurable* (and hence *cardinal*). Instant utility therefore comprises part of the basis for the scientific formulation of human behavior.

We will soon return to the epistemological considerations that guide and validate the formulation of human behavior. First, the Gossen equation is introduced. Because the Gossen equation has prominent antecedents going back over 200 years, it will be simply written in its final form rather than provide the historical and present development.[7] Accordingly,[8]

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[4] An important consideration here is that neuroscience and the Bayesian/subjective approach may resolve objective-ambiguity in certain decisions (for background see Ellsberg 1961)

[5] For further discussion see Georgescu-Rogen's introduction to Gossen (1854 [1983]) and his article "Utility" in the Encyclopaedia of the Social Sciences" (1968).

[6] This is not to imply that humans merely hedonistically optimize expected pleasure/pain—a frequent criticism of utility theory. But it is maintained in the present theory that people maximize their anticipatory assessment in formulating and following plans—where it is important to note that overriding compulsions, habits, etc., may, or may not, be recognized in the individual's expected action-scenarios. From the dimensional/empirical perspective, the anticipatory assessment takes the form of instant-utility (feeling state). This is the mathematical statement that people do what they want—subject to the overriding expected (and frequently unexpected) "constraints" of every kind.

[7] See Chamberlain [1997] for the development of the Gossen equation. Here it may be noted that the plan designation k is absent from the equation. This reflects the understanding that the deliberation among several candidate plans, following the "old" plan negation by surprise, is itself a planned activity. This does not mean that retention of the plan designation is necessarily wrong. In this regard, its retention may be of value in instruction, and in the modeling of human planning.

[8] To briefly reiterate, we adopt the heavy underline convention to clearly distinguish present, real-time cognitive function versus expected function in the intertemporal future. Accordingly, "$\underline{UT} =$" in standard theory refers to the total intertemporal utility (possibly discounted) of the individual's plan. In the present

(1a) $$\underline{E^i \;=}\; \sum_{w=1,\infty} [f^i_w \int_t^\infty \lambda^i_w(.,.,\ldots,t)\, P^i_w(.,.,\ldots,t)\, dt]$$

subject to the expected constraints

(1b) $$\Phi^{ic}_w = 0, \qquad c(w) = 1, \infty.$$

In this formulation the expected instant-utility (or feeling state) P at a future time t is subliminally or autonomically discounted by the emotive factor λ. Integration of this product along its worldline w to the intertemporal horizon yields the corresponding total utility (along this specific worldline). Applying the occurrence-probability factor f to the worldline's total utility and summing over the infinite number of worldlines making up the individual's expectational plan results in the his or her psychosomatic anticipation E of the plan. Of the several candidate plans that may be considered at a point in real time, the one providing the most positive (or least negative) psychosomatic response (i.e., feeling state) is chosen. Note that all terms to the right of the equal sign of (1a) along with (1b) in total are expectational in character. The expression "$\underline{E^i \;=}$" is purely real-time in character, as signified by the heavy underline.

As further explanation, the worldline w is a novel concept wherein each worldline represents the expected-time projection of one intentional scenario of the infinite number of such projections, to time infinity (or the intertemporal horizon).[9] In the individual's expectational plan it is recognized that the progress of real time gradually extinguishes uncertainty (a manner of learning) , and thereby eliminates or terminates the corresponding worldlines.

An important feature of human planning, and hence of the Gossen equation, is that planning tends to be focused. For example, the CEO who is thinking about the effect of uncertain corporate performance on the value of a new bond offering is not likely to simultaneously reflect on proposed changes to the company pension plan. Eventually, in the normal course of

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theory, "$\underline{E^i \;=}$" is the (always discounted) intertemporal utility assessed/addressed/realized as a psychosomatic feeling-state rather than a cognitive or intellectual realization (as in standard theory).

[9] Here we recognize that instead of thinking about discrete, noteworthy expected events in an individual's life, as is common in the discipline, we recognize that every instant of the individual's life may be considered an event. Joining these into a continuous locus of such instants then produces the worldline. And just as the individual may assign an occurrence probability to the expected event, so he or she assigns a probability to the expected worldline.

experience, circumstances will cause us to reflect on all areas of interest. Typically, however, our intentional action scenarios will deal with the more immediate concerns. And so our planning covers all time scales, within the context of "overarching" long term planning.

Returning to (1a), the discount function λ is a subjective factor that transforms expected experience into a current real-time anticipatory instant-utility E. This instant utility enters into and affects the individual's cognitive function and decisions, but it is not the exclusive basis for determining the course of action. In particular, cognitive function below the individual's awareness can affect behavior. When this happens the individual's intention may be changed, however slightly. It is understood, then, that an operative Gossen equation, along with its constraints, is short-lived—that is, the operative plan is temporary and almost continuously "updated" or adjusted due to novel or unexpected information entering the conscious and subconscious.

For the purpose of an initial discussion, it can first be noted that Ramsey's formulation (1928) is similar to (1a) and (1b). As a particular, he represented the instant utility of both production and consumption—but not leisure—in his integral expressions. However, a detailed examination shows that whereas productive activity-duration is explicitly recognized in his modeling (for example, in the intrabalance condition,[10] and the budget equation), consumption as an elementary human activity-duration over time is not represented.[11] More generally, Ramsey did not treat uncertainty f, and he recognized this omission as an important shortcoming of his paper (p. 549). Additionally, psychological discounting λ of expected pleasure/pain was initially rejected ("…ethically indefensible and arises from a weakness of the imagination" [!]), but he did address it in a general way later in the paper. His formulation has been recognized as an important contribution to mathematical economics. Of potentially very great value in the

[10] *Intrabalance* is a verbal contraction of "intratemporal marginal utility balance"—i.e., balance of activity marginal utility (productive, consumptive, and leisure) within the single day. Similarly, *interbalance* is a verbal contraction of "intertemporal marginal utility balance"—i.e., balance of activity marginal utility over intertemporal time. In either case, balancing occurs on the single worldline, or a coincident subset of worldlines. Interbalance ultimately encompasses the entire expectational plan, with worldline-uncertainties as moderators in the individual's plan-formation.

[11] As will be seen, consumptive activity was indirectly represented by Ramsey—that is, consumptive activity was represented in terms of the quantity of goods consumed per unit time. The fact that individuals spend "clock" time in the process of consumption was ignored. (In this regard, consumptive instant utility U in Ramsey's paper depends on x(t), where x has the units of goods consumed per unit time. This is equivalent to utility per unit good.)

instant utility approach is his modeling of intermittent (on/off) instant utility of a given activity as continuous or averaged over time. (This transformation is prominently addressed in a critique and extension of Ramsey's work later in the present paper.)

Continuing with the overview, it can be noted that (autonomic) discounting λ and occurrence probability f are novel or new in certain ways. λ differs from the standard definition by having a psychosomatic basis rather than a purely intellectual or rational basis (its dimension is [TIME^{-1}] in the present methodology, versus dimensionless in earlier studies). Occurrence probability f—long recognized in the literature (e.g., Jevons 1871; and Strotz 1956)—has its basis in the (apparently) new idea of the discrete worldline w of human and economic activity. The postulate that individuals (partly) direct their activity on the basis of psychosomatic affect, due to anticipation of a (mental and physical) action-scenario, is not new (Ehrenfels 1892; Shackle 1958, pg 41), and recent biopsychological studies of brain-damaged patients and normals support their insight (Damasio 1994; and Bechara, et.al. 1997).

The Gossen equation accounts for uncertainty in the individual's mind as to the "choices" that will be made as action proceeds according to plan. Here the term "choices" is in quotations, as usual, inasmuch as all "decisions" are *conditionally predetermined* in the present theory. In this regard, if the individual plans to take path A rather than path B unless he sees a tiger on path A, is the decision made upon spotting the tiger? No, the decision was made at the time of plan initiation. Much, if not all, planning is of this character—whether an individual is walking a risky path, or a CEO is charting the course of a Fortune 500 company. Decisions are *conditionally made* in the present theory, and are implicit in the plan.[12] Decisions are revealed as uncertainty is extinguished, and knowledge gained, with the progress of real time.

2.1 Qualification of the Gossen Equation

It was noted earlier that cognitive function is subject to natural law. Whether this means that quantum mechanics is *essentially germane* to consciousness is an open question. However, it is useful to draw certain parallels between quantum-mechanics and human expectation.

[12] Creative ideas can "bubble up" as the CEO ruminates. These negate the old operative plan and install the new, complete with implicit "decisions." What remains for the CEO is to research, reflect, and learn, according to plan, to reach the (previously uncertain) decision.

In either case, the state is short-lived. In quantum mechanics, it is only quite recently and with great ingenuity and skill that *coherence* has been shown to apply to the macro-world (Friedman, et. al. 1999). In this regard, disturbances by the environment continually impinge on any given (finite) subsystem, thereby constantly altering its state. The same is true in the individual's plan of action. The unexpected—affecting cognition from both the outer world and the inner (neuropsychological) world—frequently changes the individual's expectation. In this sense, the Gossen equation for a biopsychological system is like the Schrodinger equation for a physical system. That is, the plan it represents is valid for finite time-intervals—from as short as a fraction of a second to perhaps tens of minutes.

Of course, a new plan emerges (or the old plan is revised) whenever the operative plan is negated by novel or unexpected information, whether consciously or subconsciously received. But this does not mean that the individual is in a kind of "random walk" existence. Despite interruptions, the individual's overarching purposeful intent is typically maintained. For example, if it is the individual's intent to cross the street and he is surprised by heavy traffic, he will wait and then cross. If a company computer unexpectedly crashes for some reason, the programmers will resume their tasks later in the day. And if a CFO plans a bond offering but interest rates suddenly spike due to some international event, a few months wait is decided. It is common for the unexpected with its new knowledge to alter our course, but we typically (but not always) return to the old plan, where the old plan may be significantly revised to accommodate the new knowledge.

Another factor besides surprise or the unexpected that serves to negate intentional plans is defective memory. Here it is of course true that plans are significantly based on memory, and our recollections can be incomplete, biased or distorted, and fabricated. Beyond this, our beliefs may be in error—for example, by assigning an extra-scientific significance to planetary alignments. Unrealistic plans are the result in either case. Nevertheless, it is certainly true that human activity can be guided by false plans. Eventually, however, the individual will be surprised by an event inconsistent with his false memories and beliefs, and a new intentional plan then results. This plan must also be flawed, despite our having learned from the experience, and is doomed to replacement. In this manner we progress into an (uncertain) future

Expectational plans—albeit fragmentary, transitory, and erroneous—can be modeled between surprises, just as the Schrodinger equation of quantum mechanics models states of nature between decoherences. And just as physicists routinely hypothesize idealized and specialized states in their applied analyses, so economists may abstract from the desultory or imperfect planning of humans to formulate models useful in economic analyses.

2.2 Epistemological Assessment

The issue now is the extent to which the instant-utility approach in its present (Gossen equation) form is legitimate and useful in explaining human behavior. To aid in this assessment we have the valuable epistemological experience obtained in the physical sciences, and also the truly remarkable neuropsychological empirical investigations of recent years. Regarding the latter we can refer to the empirical basis for : intention (Wickelgren 1999); expectation (Fetz 1997; Logothetis 1999); anticipatory instant utility (Price 2000);[13] uncertainty (Schultz, et. al. 1997); surprise (Barinaga 1997);[14] learning (Schultz, et. al. 1997);[15] discounting (Damasio 1994); activity instant utility (Rolls 1975;Rainville, et. al. 1997; Tataranni, et. al. 1999; Price 2000); imaginary time (Snyder 1997; Logothetis 1999; Price 2000); and constraints (Snyder 1997).

In view of the foregoing discussion, we now conclude that—

> Because mental function does not transcend physical reality, it is entirely within the physical world that we investigate consciousness and human behavior. In this regard, the psychosomatic parameters relevant to mental function are definable and measurable, as in physics. It is accordingly concluded that human planning—and behavior—can be modeled, as physical processes can be modeled in physics.

[13] According to Price, "Unlike pain, unpleasantness, secondary pain affect [anticipatory instant utility] is based more on elaborate reflection related to that which one remembers or imagines. This involves meanings such as perceived interference with one's life, difficulties of enduring pain over time, and the implications for the future." (Emphasis added; p. 1769)

[14] Although, strictly speaking, surprise is absent from planning.

[15] This paper is strongly supportive of the present theory—in particular that (one form of) learning is due to the extinction of uncertainty as the plan is followed. As stated in the article: "Behavioral experiments suggest that learning is driven by changes in the expectations about future salient events such as rewards and punishments." (Emphasis added.)

Inasmuch as the Gossen equation (1a,b) is a basic formulation of the elements of expectational planning, and these elements are empirically measurable, it is concluded that the formulation is a scientific model of human intention and planning.[16]

The above may be judged a bold statement, but is this not what is required? After all, basic theory and fundamental principles are not derived—they are postulated, in view of the empirical data they represent. The statement should be made, as a necessary part of the progress of science. The purpose of this article is, in part, to make the statement, among other similar statements, and thereby promote the development of behavioral science.

This, however, is not sufficient. It is required, in addition, that the overall theory be testable. Should this not be the case then the theory resides outside of the bounds of science. But if the Gossen equation has an empirical foundation, in the sense defined above, and is testable, *then without further qualification it properly resides within the domain of science.* The question then is not whether the theory is scientific, but the extent to which it is correct.

The strength of the present theory rests with its explanatory power, and also with its predictive power (that is, in the "what if" sense, rather than absolute sense). Some evidence of this rests with the insight that the theory permits into economic behavior and social psychology, as discussed below.

3.0 METHODOLOGY IN THE SOCIAL SCIENCES

It is understood that cognitive function is not transcendent of the material universe in some sense, but is subject, ultimately, to the same physical processes that can be discerned in physics experiments and observations. (Here I share the belief of many behavioral researchers that quantum indeterminacy is fundamental to consciousness.) As a further point, neuroscience is rapidly establishing the empirical links between the natural and social branches of science. From these considerations it may be concluded that social science and natural science are coming together, on the same basis, to be joined at an integrated interface. However, this can only occur if substantially the same epistemology—"methods and grounds of knowledge, with reference to

[16] This is not to imply, of course, that the Gossen equation is the absolute and final representation of human behavior: As in natural science, theory is provisional, to be further developed on the basis of deeper studies and empirical finding.

its limits and validity"—and methodology exist on both sides of the interface. And this requires that mathematical (economic) behavior adopt an empirical foundation analogous to physics, and then employ a similar methodology (for examples, regarding methodology: mathematical simplifications must be justified, with reference to fundamental considerations [empirical and conceptual]; and equations must be dimensionally consistent, term-to-term).

3.1 Economics

3.1.1 Derivation of Standard Economic Theory

As discussed earlier, the Gossen equation (and expectational constraints) provide the mathematical basis for behavior theory. It remains, then, to show how connective theory may be established between this foundation and the methodology of behavioral science (in particular, economics). For this purpose, two branches or compartments of economic theory are addressed immediately below—equilibrium theory and real business cycle theory.

It will be seen in the following derivations how the present methodology connects, or analytically relates, the two very different formulations of economic theory. This is accomplished by deriving the Gossen equation starting with real business cycle theory, and then using the Gossen equation to arrive at equilibrium theory. A nascent or beginning classification of economic theory is thereby demonstrated, this, of course, being part of the nature of science.

3.1.1.1 Real Business Cycle (RBC) Theory.

In this derivation we begin with RBC theory in a standard form, and introduce assumptions that ultimately yield the Gossen equation. The fact that RBC theory is similar to the present approach in several basic respects helps this "reverse derivation."

In RBC theory a representative agent who is both a producer and consumer maximizes the following objective function (see Hartley, et. al. (Eds.) 1998, p. 9):

$$\underline{\mathrm{UT} = \mathrm{UT}}(\{\mathbf{C}_t\}, \{\boldsymbol{L}_t\}).$$

$\{\mathbf{C}_t\}$ and $\{\boldsymbol{L}_t\}$ are, respectively, "..the set of current and future levels of consumption, and … the set of current and future supplies of labor (the time subscript t has the values 0, 1, 2, …, ∞)." $\{\mathbf{C}_t\}$, in accordance with standard neoclassical theory, has the dimension [GOOD]—e.g., an element of $\mathbf{C}_t$ could be the amount of a particular kind of food consumed in the intertemporal sub-interval t. Something, however, immediately catches the eye of the applied mathematician in physics and engineering—consumption and labor are both activities, but the consumption side has the dimension [GOOD] while the labor side has the dimension [TIME]. To the analyst in the physical sciences, this inconsistency in mathematical expression, when encountered, directly undermines confidence, and in fact should require a substantive review. The condition is readily corrected: Change consumption amounts $\{\mathbf{C}_t\}$ to consumption *durations* $\{\boldsymbol{C}_t\}$ with the dimension [TIME]. Also, for completeness, we recognize leisure or rest $\{\boldsymbol{R}_t\}$. Now a revised objective (utility) function is acquired, i.e.,

$$\underline{UT} = \underline{UT}(\{\boldsymbol{C}_t\}, \{\boldsymbol{L}_t\}, \{\boldsymbol{R}_t\})$$

Simply changing *consumed amount* to *consumption duration* opens the door to a more substantive and concise theory. As a particular, a single integral expression (for each individual) covering the entire intertemporal period may be obtained

$$\underline{UT} = \int_0^\infty IU(.,.,\ldots,t)\, dt$$

where IU now represents the instant utility of labor, consumption, or leisure at the time it is expected, with the function given a general dependence.[17] This formulation, having an analytic character, naturally accommodates uncertainty f_w and autonomic discounting Π_w:

$$\underline{UT} = \sum_{w=1,\,\infty} f_w \int_0^\infty \Pi_w\, IU_w(.,.,\ldots,t)\, dt$$

where the summation occurs over an infinite set of worldlines w. Recognizing that one such operative equation applies to each individual, the superscript "i" is appended. Furthermore, the individual, in initiating the operative plan, chooses among alternatives, designated by the subscript "k". The formulation accordingly becomes

$$\underline{UT^i_k} = \sum_{w=1,\,\infty} f^i_{kw} \int_0^\infty \Pi^i_{kw}\, IU^i_{kw}(.,.,\ldots,t)\, dt.$$

[17] There is the issue as to whether leisure (or rest) is not itself a form of consumption, since the activity seldom, if ever, makes no use of a consumable (e.g., bed). But we will continue to make the distinction for now, since we intuitively discern between active consumption and passive sleep (for example).

This expression is not far removed from modern mathematical economics. The major departure is the occurrence of productive and consumptive instant utilities *as non-coincident states or conditions in the same formulation*.[18] Subjective uncertainty f^i_{kw} is, of course, recognized in mainstream theory, although the present formulation in terms of *worldlines* appears to be novel. But the discount function Π^i_{kw} is not novel, having, for example, been prominently employed by Strotz (1956) in his study of myopic effect in expectational planning.

One more adjustment is required to arrive at the Gossen equation of the present approach. The adjustment is to assign the dimension $[TIME]^{-1}$ to the discount function. In mainstream theory Π is dimensionless. This is, however, a troublesome arrangement. As a fundamental consideration, salient parameters in scientific theory should have some meaningful relationship to the physical world, and this requires dimensionality. Furthermore, without Π having a dimensional character one is left with intertemporal utility maximization as a purely intellectual exercise (unbounded rationality)—a superhuman capability that is not supported by introspection and cognitive science. The alternative is afforded by theoretical studies (e.g., Ehrenfels (1896); Shackle (1956)) and psychosomatic investigations (Damasio (1994))—i.e., people choose among alternative action-scenarios such that the instant utility [PLEASURE (feeling state)] of anticipation is maximized. Accordingly, Π is replaced by λ with the dimension $[TIME]^{-1}$, thereby converting expected intertemporal utility $UT\rangle^i_k$ to anticipatory instant-utility E^i_k. With this change the Gossen equation is obtained (Chamberlain 1998a):[19]

(1a) $$\underline{E^i_k =} \sum_{w=1,\infty} [f^i_{kw} \int_0^\infty \lambda^i_{kw}(.,.,\ldots,t)\, IU^i_{kw}(.,.,\ldots,t)\, dt]$$

subject to the expected constraints

(1b) $$\Phi^{ic}_{kw} = 0, \qquad c(w) = 1, \infty.$$

This formulation represents the expectational plan of the individual—i.e., it represents either the operative plan that guides the individual's actions or a candidate plan (following a plan-negating surprise of some kind) soon to be implemented, or passed over.

[18] As has been noted, this condition is methodologically rejected by the keystone *consumerism* assumption of standard theory (wherein utility is directly assigned to commodities).
[19] In the earlier papers the symbol P has been used instead of IU.

3.1.1.2 Equilibrium Theory.

We now turn to derivation of equilibrium theory from the Gossen equation—following an introductory overview.

Equilibrium theory is widely recognized as the core of mainstream or standard (neoclassical) economics. Hausman (1992, p. 30, 43, and 53) has identified seven basic assumptions of modern equilibrium theory:

EQUILIBRIUM THEORY[20]

Consumer Choice Theory
1. Rationality
2. Consumerism
3. Diminishing marginal rates of substitution

Theory of the Firm
4. Diminishing returns
5. Constant returns to scale
..6. Profit maximization

Equilibration
7. Equilibrium attained

As a brief overview, it may first be noted that Consumer Choice Theory represents economic behavior as "rational greed" [Ibid., 33]. In this understanding, an individual may be judged *rational* if he is consistent in his preferences [Ibid., 13]. *Consumerism* holds, in part, that the objects of the individual's preferences are bundles of goods for his own selfish consumption, where larger bundles are preferred over smaller, up to the point of satiation [Ibid., 30]. According to the third law, *Diminishing marginal rates of substitution*, the individual will trade less of a given good for another the more of the latter in possession [Ibid., 30]. Theory of the Firm is sufficiently familiar to suspend comment. The seventh assumption, *equilibrium attained*, may be understood to stipulate that all participants collectively negotiate the price structure that "clears" the market of excess supply and demand, in an economic system that quickly achieves equilibrium

How do we apply these assumptions to the Gossen equation?[21] It may first be observed that rationality (#1) stipulates, in part, the absence of uncertainty in the individual's planning,[22] and also the absence of surprise that would change the plan (however slightly). Uncertainty is suppressed by dropping f^{i}_{kw} (and kw) from the Gossen equation. But note that by suppressing uncertainty the individual is assumed to have perfect and complete knowledge of present and future economic reality, including the mental and physical function of every individual in society. That is, the agent is now computer-like—in the sense of obtaining specific outcomes from specific conditions and processes. An important consequence is that there can be no learning through uncertainty extinction (this being a mode of learning). The absence of surprise is easily accommodated by postulating that the expectational plan of each individual is never negated by unexpected new information, including spontaneous, or creative, cognitive function, conscious or subconscious. This has the corollary or secondary effect of requiring an exponential λ, in particular $\lambda = \underline{\lambda}^{i} \exp(-\alpha t)$, in order to permit rational planning (i.e., to avoid plan-negation with the advance of real time due to inconsistent discounting.[23] See Strotz 1956). $\underline{\lambda}^{i}$ must also now be non-dimensional, since pure rationality denies emotion and feeling. The remaining conditions for rationality (e.g., transitivity) are satisfied by casting preferences in terms of a (commodity) utility function.

Next we address equilibrium (#7). Equilibrium doesn't mean, of course, that time, and activity, are frozen, rather it means that economic activity, in its balance and dynamics, is *periodic*. In particular, every state of the economy *recurs* at precisely regular intervals (for example, day-to-day, or season-to-season).[24] Accordingly, for periodic activity along with the attending periodic psychosomatic affect,

$$IU^{i}(t^{*}) = IU^{i}(p+t^{*}) = IU^{i}(2p+t^{*}) = \ldots =. IU^{i}(n\,p+t^{*}).$$

[20] Equilibrium theory must, according to Hausman, be distinguished from general equilibrium theory, the latter constructed on the foundation of equilibrium theory through the introduction of (additional) assumptions.

[21] It is understood, unless otherwise specified, that all references to activity, utility, instant utility, etc., are with regard to *expected* experience.

[22] This is central to microeconomics (Hausman 1994, p. 22). Uncertainty can be accommodated, as in expected utility theory, but this requires utility cardinality, in opposition to ordinal utility of standard theory (Ibid., 22-24).

[23] An essential aspect of the IU approach is that myopic adjustment is expected (part of the plan) when the individual recognizes his or her "non-exponential" discounting.

[24] See the 2000 paper for further discussion.

In accounting for periodicity, the first step is to divide intertemporal time into separate, and equal, segments (e.g., days). Incorporating this change, along with the additional changes earlier discussed, converts the Gossen equation into

$$\underline{UT}^{i} \equiv \sum_{n=1,\infty} [\underline{\lambda}^{i} \int_0^p \exp(-\alpha\{[n-1]p + t^*\})\, IU^i([n-1]p + t^*)\, dt^*]$$

where total intertemporal utility $\underline{UT}^i$ (discounted), with dimensions [PLEASURExTIME], now takes the place of anticipatory instant utility $\underline{\underline{E}}$.[25] Taking account of periodicity allows[26]

$$\text{(2)} \qquad \underline{UT}^{i} \equiv (1/[1 - \exp(-\alpha\, p)])\, \underline{\lambda}^{i} \int_0^p \exp(-\alpha\, t^*)\, IU^i(t^*)\, dt^*.$$

The ensemble of constraints on individual and firm behavior are similarly cast in (compatible) periodic form. Note that intertemporal discounting remains explicit, and finite, in Eq. (2)—a condition that is suppressed in the next assumption, consumerism.

<u>Consumerism</u> (#2) focuses the individual's purposeful living on his or her consumption. This is formulated by assigning utility to consumables, while ignoring labor and rest instant utility.

Consumerism is recognized in the Gossen equation by first setting the process-of-knowing IU equal to zero for all expected labor and leisure. Eq. (2) accordingly becomes

$$\underline{UT}^{i} \equiv (1/[1 - \exp(-\alpha\, p)])\, \underline{\lambda}^{i} \int_0^p \exp(-\alpha\, t^*)\, IU^i_C(t^*)\, dt^*$$

where IU^i_C is piecewise continuous and finite for the diverse consumptive activities in p, and zero otherwise. The equation may be written as a function of the consumptive activities

$$\underline{UT}^{i} \equiv F^i(C_A, C_B, C_C, \ldots)$$

where each C_μ is the periodically recurring activity in the consumption of consumable μ in the individual's expectation. Standard microeconomics, of course, usually takes commodities to be fundamental rather than consumptive activity. Accordingly,

[25] Note that we retain the real time designation (i.e., $\underline{UT}^i \equiv$) for the individual's "calculation" of the plan's intertermporal utility.
[26] See "Periodic Functions," Kreyszig 1965 ,p. 223.

$$\underline{UT^i = F^i}(Q_A, Q_B, Q_C, \ldots)$$

in terms of consumed amounts Q_A, Q_B, etc. [27] (This is the momentous postulate (by Walras 1872-76) on which basis microeconomics (and macroeconomic extensions) have largely developed over the past 120+ years.) Consumptive activities are now deemed superfluous or irrelevant since utility is directly assigned to consumables, and they are dropped from the constraints. In addition, the time constraint is itself superfluous or irrelevant, and is dropped. Utility, originally and correctly cardinal, accordingly becomes ordinal. Note that Q_μ is the quantity of consumable μ consumed in a single period—expectedly unchanging to time infinity.

Diminishing marginal rates of substitution is achieved as usual by requiring diminishing marginal utility of all consumables. This leaves the three assumptions of the Theory of the Firm.

Diminishing returns (#4), constant returns to scale (#5), and profit maximization (#6) of the Theory of the Firm affect the individual's utility calculus only indirectly and are formulated entirely in the constraints (1b). The assumptions are represented as in standard theory.

This completes the derivation of Equilibrium Theory from the Gossen equation. To briefly revisit, the crucial assumption in this derivation is to set aside human activity instant-utility in favor of direct and exclusive assignment of utility to market-commodities. Mathematical formulation thereby becomes incomplete—and it resides at a nonessential level (i.e., from the standpoint of the theory of knowledge). For example, utility is necessarily ordinal (see Hicks 1939, pp. 1-6), rather than retain cardinality of real human/economic life. As a consequence, the mathematical "richness" that could accommodate subjective dimensions is lost.

A few comments are offered to conclude this section. …As evident in physics, the formal connection or relationship between basic theory and applied theory yields practical scientific benefits. A form of classification is the essence of these benefits. In fluid mechanics, for example, there are many categories of motion of gases and liquids, each category with simplifying and/or specific mathematical assumptions. These categories tend to seamlessly blend or transition into each other. It is the underlying *basic* physics, along with similar methodologies, that permits this coherent and consistent framework. The great technological success over the

[27] For a critical discussion see Georgescu-Roegen's introduction to the English translation of Hermann Gossen's book (1983) on instant-utility theory.

past several centuries is significantly dependent on this classification in fluid mechanics, and the several other branches of physical science.

This classification in the physical sciences is possible in the social sciences, as indicated in the preceding derivations. In this regard, the preceding formulations of real business cycle theory and equilibrium theory on the basis of the Gossen equation show how widely different economic approaches can be systematically related. But the benefits of course extend beyond the confines of economic science, inasmuch as economic psychology, sociology, and institutional economics may also be arranged in a classified or inter-related manner, on the basis of the Gossen equation. An advantage of some immediacy is the reconciliation of economics with its sister sciences—sociology in particular—as a consequence of wants, desire, evaluations, etc. acquiring a common *endogenous* character at the fundamental level (See Baron and Hannan 1994). (It may be reiterated, in this connection, that wants and preferences in equilibrium theory and RBC theory are necessarily *exogenous* due to the direct identification of utility with consumables.)

3.1.2 Methodological Example: Saving

It is important to acknowledge that modern economic theory does recognize time despite its timeless character in core (equilibrium) theory. The work of Ramsey in his 1928 paper is perhaps the most far-reaching attempt to formulate a time-dependent model in neoclassical theory. His approach is very much in the "instant utility" vein and departs from the present methodology (i.e., as far as his approach was developed) in only a few limited, but crucially important, ways. Foremost among these is the epistemologically proper way to introduce utility into economic science.

Because Ramsey made important use of the instant-utility approach, it appears advantageous to develop the following model along the lines of his 1928 contribution—"A Mathematical Theory of Saving". This will help to sharply define how the present methodology differs from, and goes beyond, mainstream theory. In addition, it will be shown how the present more fundamental approach extends Ramsey's rule for saving—in particular, to account for discounting of expected activity-duration utility as a consequence of normal psychosomatic function, and also as a consequence of expected investment-risk. In extending this rule we focus on saving by the individual agent rather than the community (as in Ramsey's mathematical study), and postulate that while the individual recognizes saving and capital/consumable accumulation as significant within his expectation-horizon, the economy at large (macroeconomy) varies slowly enough that it does not affect his expectational planning. (The individual's economic activity in this regard has no effect on the macroeconomy—this being, incidentally, a common assumption in neoclassical mathematical economics.)

Ramsey stated this rule as follows:

> "The rate of saving multiplied by marginal utility of consumption should always equal bliss minus actual rate of utility enjoyed." (Ibid., p. 547)

In deriving this rule, Ramsey, as noted above, ignored uncertainty (more specifically, investment-risk) and autonomic discounting. We will shortly account for these effects in extending his rule for saving.

A word on Ramsey's concern about risk in economics, and its neglect from his study, may be helpful. He wrote:

> The most serious factor neglected [in the analysis] is the possibility of future wars and earthquakes destroying our accumulations. These cannot be adequately accounted for by taking a very low rate of interest over long periods, since they may make the rate of interest actually negative, destroying as they do not only interest but principal as well. (Ibid, p. 549)

In fact, the recognized possibility of a general loss of possessions serves to increase the interest rate. In this regard, the uncertain prospect of an economic setback is similar, in its mathematical particulars, to intertemporal discounting, as will be demonstrated below.

Before proceeding with the overview of Ramsey's methodology, followed by the present critique and revision, several qualifications are appropriate. First, it should be noted that Ramsey's analysis in proving his savings-rule was based on only one of several factors that yield positive interest rates. In particular, he used the "better times ahead" basis (see his Eq. 3 on page 546)—this being one of three that Bohm-Bawerk postulated would cause a finite interest rate (Bohm-Bawerk 1889-1911).[28] The other two according to Bohm-Bawerk were: (a) virtual

[28] Ramsey did not state that his analysis was based on the "better times ahead" hypothesis. In this regard, the "better times ahead" hypothesis automatically generates a growing economy with a finite interest rate, until bliss is achieved (at which time the interest becomes zero). In the present more fundamental approach, a finite interest rate is retained even in the equilibrium bliss condition.

discounting of expected experience (instant utility), and (b) expected finite life-span. There are other causes as well. In particular: (1) expected probability (less than 1.0) that future returns from present investments will in fact be realized (addressed later in this paper); and (2) growth of technological knowledge (see Knight 1944). Later in the paper, in a linear analysis, we will show how autonomic discounting and expected-risk may be included in Ramsey's rule for saving.

Ramsey employed a simple transformation of intertemporal utility that significantly helps or aids the application of differential and integral calculus in economics, and this transformation will be used below. He was clearly thinking of *community* utility in his paper, but he believed that his methodology represented the individual's planning as well (page 554).

Ramsey introduced instant utility by denoting U(x(t)) as "..the total rate of utility of a rate of consumption x" and V(a(t)) as "…the total rate of disutility of a rate of labor a."[29] He immediately went on to state that "…the corresponding marginal rates we will call u(x) and v(a)," and defined these as:

$$u(x) = dU(x)/dx$$

$$v(a) = dV(a)/da.$$

It can be noted here that we consider it quite helpful, if not mandatory, to think in terms of *dimensions* in assessing theoretical development. Accordingly, both U(x) and V(a) have the dimension [PLEASURE (ie, feeling state)] of instant utility. Ramsey's language is consistent in this regard—in his referring to U(x), for example, as the total rate of utility. The rate of consumption "x" has the dimensions [GOOD/TIME] and "a" is dimensionless (as discerned from his analysis in general). Because U(x) has the dimension [PLEASURE], u(x) must have the dimensions [PLEASURExTIME/GOOD]—i.e., utility per unit good. By identical logic but with a different *dimensional* result, v(a) has the same dimension as V(a), that is, [PLEASURE] (because "a" is dimensionless).

Besides paying careful attention to dimensions in theoretical studies it is of course important to assign the most meaningful terms. In this regard, what Ramsey refers to as the total

[29] Here we may note a logical inconsistency: The rate of labor is not the same kind of thing as the rate of consumption, although the wording is similar. This inconsistency, to be shortly discussed, reflects a fundamental difficulty in neoclassical theory.

rate of utility U (or V) is better referred to as the average rate of utility. This becomes clear in the mathematical definition of U(t):[30]

$$U(t) = (1/\tau) \int_{t-\tau/2}^{t+\tau/2} \delta_U(t') \, IU(t') \, dt',$$

where τ is the length of day (24 hours) and $\delta_U(t') = 1.0$ during the consumptive activity and zero otherwise. Similarly, the rate of consumption x is the average rate of consumption, or

$$x = (1/\tau) \int_{t-\tau/2}^{t+\tau/2} X(t') \, dt',$$

where X is the instantaneous rate of consumption during the consumptive activity.

Implicit in the foregoing, however, is an important assumption. The assumption is that discounting, including expected (investment) risk, varies so little over the course of the single day that it can be ignored in defining the average instant-parameters. (Ramsey did not give attention to this and other aspects of his average instant-utility methodology.) This assumption could be understood to reasonably represent real economic behavior—for normal agents in normal conditions.

At this point it is helpful to simplify. When Ramsey referred to the marginal rates u(x) and v(a) he was referring to the marginal rates of total utility (of the entire community). This can perhaps best be understood in terms of the marginal rates of utility for the individual. Then v(a) is the **utility per unit time** of production at the final moment of his or her (periodically recurring) productive activity-duration [TIME]—that is, it is the experienced marginal **instant-utility** [PLEASURE] of production. In an analogous manner, u(x) is the **utility per unit good** at the final moment of consumption [GOOD/TIME]. (This is equivalent to the marginal instant-utility per unit rate of consumption [PLEASURE/(GOOD/TIME)]). But again note that v(a) and u(x) have different dimensions. Besides being a source of confusion, the inconsistency is a barrier to building the framework that relates standard microeconomics to the underlying epistemological foundation.

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[30] To simplify, we assume in the present study that the rate of consumption [GOOD/TIME] is constant. This enables the postulate that IU is only a function of the consumption duration—where IU typically diminishes with consumption duration.

It is not merely for style and convenience that the utilities of productive and consumptive activity at the margins should have the same dimensional foundation. As an epistemological concern, if v has the dimension [PLEASURE (feeling-state)] then u should also have the dimension [PLEASURE], as observed by the prominent economist Georgescu-Roegen in his introduction to the English translation of Gossen's book (1983, p. lxxxi). This means that u is properly understood as u(b) = dU(b)/db, where b(t) is entirely analogous to a(t)—in particular, just as a(t) is the (nondimensional) ratio of the productive activity duration to the daily interval (24 hours) so b(t) is the (nondimensional) ratio of consumptive-activity duration to the (same) daily interval.[31] An important immediate consequence of this consistency is the fundamentally correct modeling of leisure, and the time constraint. Here the proper modeling of the constraint on time—time being the ultimate scarce resource in economics—could have special significance. Indeed, it is believed that without a proper modeling of time in mathematical economics, an exact modeling of capital and interest cannot be achieved.

> Henceforth in the present work, the symbol U (upper and lower case) is understood to be solely dependent on b(t), in the manner consistent with V and L. As a related change, marginal utility per unit good now becomes marginal anticipatory instant-utility (feeling-state) per unit good, designated by italics, i.e., *u*.[32]

Having departed from Ramsey's approach by differing on the epistemologically correct way to introduce utility into economic theory—that is, utility should be originally and exclusively identified with *human activity-duration*—we can now address methodology. In demonstrating the present methodology, Ramsey's rule for saving will be extended. This extension will be performed within a larger scope or parameter-range that takes account of autonomic discounting and expected investment-risk. Ramsey's formula will be seen to emerge or remain when the additional factors are suppressed (but with a basic qualification).

[31] The rate of consumption x is not lost by this more fundamental formulation, of course: as is the case in Ramsey's paper, it continues to enter the model and mathematics by way of the constraints. However, it now has an explicit and exclusive (as a present simplification) functional dependence on consumption activity-duration.

[32] It may be emphasized, however, that the analyst remains free, of course, to postulate that agents prepare expectational plans as a purely intellectual exercise, as has been standard in neoclassical economics. While this understanding is not supported by modern neuropsychology, and our intuitions, it may be useful as an interim approach that makes use of the instant-utility mathematics.

3.1.2.1 Savings Rate (Ramsey's Rule)

We begin by rewriting the Gossen equation in terms of continuous instant utility, in the manner of V and U discussed above but with leisure instant utility included. Subjective discounting is retained—in its conventional exponential mode to avoid myopic re-planning (see Strotz 1956). Uncertainty (risk) is suppressed for now. Accordingly,

$$(3) \qquad \underline{E_t} \cong \int_t^{\infty} \lambda \exp(-\rho\, [t'-t])\, [V(t') + U(t') + L(t')]\, dt$$

where, as addressed earlier, $V(t') = (1/\tau) \int_{t'-\tau/2}^{t'+\tau/2} \delta_V(t'')\, IU(t'')\, dt''$ with $\delta_V(t'') = 1.0$ during the labor activity and zero otherwise. Similarly for U and L. λ is assumed constant. In our treatment we postulate that the macro-economy varies so little to the "discount horizon"[33] that it is effectively stationary so far as the individual's planning is concerned. It is seen, therefore, that (a) long-term (macroeconomic) changes are ignored in planning by the individual due to "relatively steep" discounting; and that (b) short-term (day-to-day) changes are ignored in his planning due to "relatively weak" discounting (i.e., during a 24-hour interval). The latter conclusion (b) validates V, U, and L as continuous functions, and the former conclusion (a) ensures that macroeconomic dynamics to not affect, or interfere with, the individual's planning.[34]

Note that the perfect-rationality assumption is implicit in the development to follow. The important particular in this regard is that each individual, and all taken together, are assumed to have complete and certain knowledge of all future conditions and activity. This assumption will be partially relaxed later in the paper when expected-risk is accounted for in planning. In this regard, the rationality assumption of equilibrium theory is in fact indispensable in economic modeling, and will be always be useful in theoretical analyses in varying degrees of relaxation.

In the present linearization we limit our analysis to (expectedly) very great times, where Ramsey's "bliss" has almost been achieved. For small departures from the asymptote, the

[33] For our exponential formulation of discounting there is no "discount horizon." But we may adopt the convention that the "discount horizon" rests at the intertemporal time beyond which expected activity has a negligible effect on planning.
[34] Ramsey invokes a number of qualifying assumptions at the outset of his paper that are appropriate to the present genre of analysis. The reader may refer his discussion for this discussion.

economic dynamics may be represented by a linear formulation to an arbitrary degree of accuracy.[35] Toward this end, (3) may accordingly be written:

(3a) $$\underline{E_t} \cong \int_t^{\infty} \lambda \exp(-\rho\,[t'-t])\,[V(t') + U(t') + L(t')]\,dt'$$

$$\cong \int_t^{\infty} \lambda \exp(-\rho[t'-t])\,[\underline{V} + \underline{U} + \underline{L}]\,dt'$$

$$+ \int_t^{\infty} \lambda \exp(-\rho[t'-t])\,[\Delta V(t') + \Delta U(t') + \Delta L(t')]\,dt'$$

where λ is postulated invariant. Underscored symbols (i.e., light underline) refer to the bliss condition. The individual is assumed to be purposeful in his planning and is, accordingly, assumed to maximize (3a), subject to the postulated budgetary constraint, that saving dκ/dt plus consumption x must equal income f(a,κ),[36]

$$d\kappa/dt + x = f(a, \kappa),$$

along with the time constraint Δa + Δb + Δc = 0 (implicit). Expressing the above equation in linear form (for small displacements from the asymptote) yields

$$d(\underline{\kappa} + \Delta\kappa)/dt \cong f(\underline{a}, \underline{\kappa}) + \underline{\partial f/\partial a}\,\Delta a + \underline{\partial f/\partial \kappa}\,\Delta\kappa - \beta\,\underline{b} - \beta\,\Delta b \text{ , or}$$

$$d(\Delta\kappa)/dt \cong \underline{\partial f/\partial a}\,\Delta a + \underline{\partial f/\partial \kappa}\,\Delta\kappa - \beta\,\Delta b$$

where it is assumed as a simplification that the rate of consumption β during the consumptive activity is constant—i.e., X is always some constant magnitude (β), or zero.

At this point we recognize the exponential character of the individual's economic behavior near the asymptote. More to the point, it is recognized that the magnitude of d(Δκ)/dt is proportional to the departures of Δa, Δκ, and Δb from their respective asymptotes (essential relationship). We may then write

[35] The solution may, of course, be extended into the nonlinear domain, albeit with increasing error. (Linearization of complex mathematical problems is standard practice in applied physics.)

[36] Of course, the individual does not have the super-human capability to achieve an identical maximization. But he or she can maximize within the context of uncertainty—including the recognized uncertainty inherent in one's own calculus of expectational planning. This of course reflects reality. Note that by neglecting uncertainty (for the present), we make valuable use of the (complete or unrelaxed) rational man assumption of standard theory.

$$\Delta V(t') = (V(t') - \underline{V}) = \Delta V(t) \exp(-(1/\sigma)\,[t'-t])$$

$$\Delta U(t') = (U(t') - \underline{U}) = \Delta U(t) \exp(-(1/\sigma)\,[t'-t])$$

$$\Delta L(t') = (L(t') - \underline{L}) = \Delta L(t) \exp(-(1/\sigma)\,[t'-t])$$

where σ is the characteristic time-constant of the individual's approach to his bliss asymptote.

With the above definitions (3a) now becomes:

$$(4) \qquad \underline{E_t} \cong \overbrace{[\underline{V} + \underline{U} + \underline{L}] \int_t^\infty \lambda \exp(-\rho[t'-t])\,dt'}^{A}$$

$$+ \overbrace{[\Delta V(t) + \Delta U(t) + \Delta L(t)] \int_t^\infty \lambda \exp(-[\rho + 1/\sigma][t'-t])\,dt'}^{B}.$$

We are interested in the rate at which $\underline{E_t}$ approaches the bliss asymptote, where this result will shortly be related to the corresponding rate at which working capital κ approaches its asymptotic magnitude $\underline{\kappa}$. The rate of approach of $\underline{E_t}$ to the asymptote is given by $\underline{d(E_t)/dt}$. Taking the derivative of (4) produces:

$$(5) \qquad \underline{d(E_t)/dt} \cong 0 - \lambda\,(1/\sigma)/[\rho + 1/\sigma]\;[\Delta V(t) + \Delta U(t) + \Delta L(t)]$$

In forming this derivative it has been recognized that the contribution of expression A in (4) to (5) is zero. (In the individual's expectation, A will always have the same value with the progress of real time. Hence $dA/dt = 0$.)[37]

Although dA/dt is zero, dB/dt in (4) is finite. The reason is that t in the integrand in connection with $1/\sigma$ is not variable. But t in connection with ρ remains differentiable, as before.

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[37] This is conceptually subtle, and additional commentary may be helpful: The key concept is the individual's (postulated) perfect foresight—he or she recognizes that the discounting-datum shifts forward in time in the time-derivative (i.e., the datum shifts from t to t+Δt in the usual definition of the derivative). Hence the integrand in A of equation (4) is differentiable, and A=0. Turning to B in (4), the datum for the asymptotic approach to bliss (time-constant σ) does not shift forward in the time-derivative. The differentiation/integration steps in B then yield a non-zero result (Note that the lower integration-limit in A and B are germane for both A and B.).

(This distinction between $1/\sigma$ and ρ is believed to be of essential importance in economic psychology.) Performing the differential and integral operations as usual yields (5).

With the understanding that it is the individual's sacrifice, or postponement, of consumption Δx (= $\Delta\kappa$) that causes the departure $\Delta V + \Delta U + \Delta L$ from the asymptotic condition, we may write $\underline{d(E_t)/dt =}$ $d(\underline{u}\,\Delta\kappa)/dt = \underline{u}\,d\kappa/dt$ in the linear limit, and (5) becomes

$$d\kappa/dt = -\lambda\left\{(1/\sigma)/[\rho + 1/\sigma]\right\} \frac{\Delta V(t) + \Delta U(t) + \Delta L(t)}{\underline{u}}$$

or

(6) $$d\kappa/dt = \lambda\left\{(1/\sigma)/[\rho + 1/\sigma]\right\} \frac{B - [V(t) + U(t) + L(t)]}{\underline{u}}.$$

at any given real time t, where B is the bliss (expected instant utility, or feeling state) on the asymptote. This is Ramsey's rule for saving, adjusted to account for autonomic or subliminal discounting.

Equation (6) is seen to be consistent with Ramsey's formulation. In particular, for $\rho \to 0$ —that is, autonomic discounting becomes vanishingly small—(6) becomes

(7) $$d\kappa/dt = \lambda \frac{B - [V(t) + U(t) + L(t)]}{\underline{u}},$$

This equivalent to Ramsey's formula, when u is substituted for $\underline{u}/\lambda$ and leisure is dropped. But note that a crucial mathematical (and conceptual) concern has been overlooked: When discounting is set-aside—as in (7) and in Ramsey's analysis—the integration of a finite pleasure to infinity is infinite (see also Blaug [1968]). Discounting of some nature, of which there are a number of modes, may always be necessary in mathematical behavior to realistically "suppress" the singularity.

(Accounting for Uncertainty)

Uncertainty—or, more precisely, (expected) event-occurrence probability—can be accommodated in our linear treatment of the economic system. As was assumed above regarding discounting (and capital), in order to avoid myopic replanning, uncertainty is postulated to (expectedly) evolve in an exponential manner. That is, given the 100% condition (or $\sum f_p = 1$) that an expected event has not occurred at t = 0, the expected probability that the event will still not have occurred at time t is $\exp(-\pi t)$, where π is a constant.

In deriving this (exponential) formulation it is convenient to model Ramsey's reference to "…the possibility of future wars and earthquakes destroying our accumulations." Accordingly, the individual imagines that in each intertemporal unit of time a small, constant risk π exists that all capital will be destroyed and the associated economic activity will cease. Then $d[\sum f]/dt \cong -\pi [\sum f]$, and it follows that $\sum f = [\sum f]_{t=0} \exp(-\pi t) = 1.0 \exp(-\pi t)$. Applying this function to (4) and rearranging gives

$$\underline{E_t} \cong \overbrace{[\underline{V} + \underline{U} + \underline{L}] \int_t^\infty \lambda \exp(-[\rho + \pi][t'-t])\, dt'}^{A}$$

$$+ \overbrace{[\Delta V(t) + \Delta U(t) + \Delta L(t)] \int_t^\infty \lambda \exp(-[\rho + \pi + 1/\sigma][t'-t])\, dt'}^{B}.$$

Here A is zero, as before, for the same reasons. This expression leads to (6) in the form

$$(8) \qquad d\kappa/dt = \lambda \left\{(1/\sigma)/[\rho + \pi + 1/\sigma]\right\} \frac{B - [V(t) + U(t) + L(t)]}{\underline{u}}$$

where it is seen that the effect of distributed expected investment-risk π is functionally equivalent to autonomic discounting ρ.

A brief recap of the above development may be helpful. This expression (8) was obtained using an approach that departed from Ramsey's in several ways. One difference was, of course, in the employment of the more fundamental (pure or substantive) instant utility methodology. Additionally, the present study addressed the approach of the individual's economic state to the bliss asymptote on a linearized (very small departure therefrom) basis, whereas Ramsey accounted for nonlinearities in a finite departure from the asymptote. Furthermore, the present analysis accounted for (autonomic and investment-risk) discounting, whereas Ramsey (initially) did not. (Ramsey later in his paper did address discounting, along the analytic line of his non-discounting analysis, a treatment which accounted for finite life-span and autonomic discounting. The result was an integro-differential expression that significantly differs from the present expression (6).)

Regarding (8), the effects of autonomic discounting and investment-risk discounting on saving appear to be in accord with our intuitions. In particular, as expected experience (feeling-state) is discounted (ρ and π increase) the rate of increase of capital-intensity is reduced, and eventually goes to zero as ρ or π increase to infinity (total discounting). At the other extreme—ρ and $\pi \rightarrow$ zero—our intuition is again served by the indicated result of increased saving. In the limit Ramsey's expression is recovered. But, as noted earlier, his expression is recovered at the cost of a hidden singularity in the mathematics.

Moving now from intuition to theory, the fact that autonomic discounting and investment-risk discounting have the same functional participation in the expression (8) indicates that expected investment risk is another factor (along with limited lifespan, better times ahead, growth of knowledge, etc.) contributing to finite interest rates. Of course, people know that risk is quite germane in determining required return-on-investment and (real) interest rates in real economic life, but the understanding has not been accommodated in the standard or mainstream methodology of mathematical economics.

3.2 Sociology

> "It is a fact that ever since the Eighteenth Century both groups have grown steadily apart until by now the modal economists and modal sociologists know little and care less about what the other does." (Joseph Shumpeter, circa 1940s, as quoted in Baron and Hannan, p. 1112—citation data show little change since the 1940s.)

It would be beneficial if economics and sociology could be brought closer together. At present the disciplines are separated for the most fundamental of reasons—diametrically opposed definitions of preferences (see Baron and Hannan 1994): In sociology preferences (valuations) are endogenous and cardinal, while in mathematical economics preferences are inconsistent—sometimes endogenous and cardinal and sometimes (formally, in core theory) exogenous and ordinal. The consequence is that modal economists and modal sociologists lack the common foundation for meaningful cooperation.[38]

This great division in the social sciences may be resolved at the fundamental level. The change is to introduce or specify utility the same way for all human activity. This, as has been discussed earlier, is accomplished by simply introducing utility as utility per unit activity-duration (that is, as instant utility, or feeling-state) for consumption as it is for labor and rest. Now the individual's, and society's, valuations of goods and services, productive and consumptive, are dependent on intentions and how intentions evolve over time (i.e., how uncertainty is gradually extinguished), and should not be arbitrarily specified by the analyst or modeler. That is, value in economic life is endogenously determined. And value is cardinal, since instant utility is cardinal (measurable). Sociology and economics would now be in agreement in their fundamental principles—the determinants of intentions, and hence actions, are cardinal and endogenous.

We've already seen where this change benefits economics by bringing mathematical consistency or coherence into theory at the most essential level. Just as economics benefits from the original, exclusive identification of utility with human activity, so her sister disciplines in the social sciences would be similarly enriched. This is partly due to economic theory becoming more compatible with social science in general, hence more useful (with a similar benefit returning to economics, of course). Mathematics is the agent—but not just any formulation. In this regard, it is of course true, in economics as in physics, that the methodology must be internally coherent or consistent. It is also appropriate, for the most important of reasons for economics as a science, that the methodology be rooted in an empirical foundation. The Gossen equation, itself a product and logical extension of the history of economic theory, satisfies these requirements.

A preliminary development of a socioeconomic model using the instant utility approach was presented at the 38th Congress of the European Regional Science Association (ERSA) in August 1998. In this study instant utility was given an explicit formulation—i.e., activity of each agent was not time-averaged or overlapping. However as we have seen above, time-averaging is

[38] Unification of Gossenian and neoclassical theory places market price-determination on the same (cardinal) plane, thereby resolving this basis for the schism.

a plausible assumption, one that significantly simplifies the mathematics. It is anticipated that the ERSA paper will be revisited to place the analysis in the "time-averaged" form. It seems appropriate for the present purposes to simply provide a nonmathematical overview of the ERSA paper.

In the 1998 ERSA paper was shown how a stereotypic bias regarding the expected productivity of a minority-population affects the productivity of the population. Here it is understood that *stereotyping* is:

> …a fundamental and probably universal bias in perception which has important and far-reaching consequences for behavior ranging from relatively harmless assumptions about people to gross practices such as genocide. It is a central component of prejudice and intergroup relations, and its study is inextricable from the study of intergroup behavior. (Hogg and Abrams 1988, p. 66.)

Because an entire minority population was addressed as having lumped properties,[39] instant utilities were aggregated over the population to yield *community instant utilities*.

Of specific interest in the analysis was the 'accentuation effect (Tajfel 1957)' attending categorization. Tajfel's *accentuation principle* holds that "…the superposition of a systematic classification of stimuli into two categories on a continuously distributed judgmental dimension results in the perceptual exaggeration of similarities within and differences between categories (Ibid., p. 71)". In economics such exaggeration could affect the prices of goods (e.g., yield an erroneous assessment of product amount versus product size),[40] and socioeconomic status/employability (e.g., bias in assessing the attributes of foreign nationals (Tajfel, et. al. 1964; see also Hogg and Abrams 1988, p. 72)). One such effect was addressed in the paper—the influence of stereotypic bias on the expected economic performance and income of a minority population.

In the study it was assumed that the categorization process has already had its effect on the economic relationship between the minority population and the (much) larger contextual population. In particular, *production per unit time*—the focal dimension—received a biased

[39] Lumped properties are used to advantage in applied physics. An example is the "lumped mass" approach in heat transfer. (See Holman 1968.)
[40] In an similar case, a study by Bruner and Goodman (1947) demonstrated that subjects erroneously identified greater sizes with higher valued coins, and conversely.

assessment (categorization) on the basis of a cultural, ethnic, racial, or gender difference—the peripheral dimension. In particular, it was generally recognized within both populations that the minority population was expected to perform at a different level—higher or lower—in its productive activity.

Stereotypic bias entered analysis through its effect on the parameters of the Gossen equation, and on the (expectational) constraints on planned activity. The sets of expected worldlines were altered—in terms of the ranges of expected action scenarios with their expected constraints, and also in terms of the (expectational) *distributed* occurrence probability across the worldlines. For example, racial bias could cause the individual to adopt an overall life-plan (worldline ensemble) that would otherwise be rejected, and then to assign distributed occurrence probability over these worldlines that reinforces the inclination to discriminatory behavior. At the more detailed level, bias would possibly enter and affect the discounting of expected instant utility, and also the expected instant utility magnitudes. Parameter magnitudes throughout the constraints could be affected.

It may be seen that that the Gossen equation (and constraints) permit the investigation of stereotyping at a deeper level—that is, permit its resolution into subsidiary or more fundamental components. The coherent treatment of human activity, and (instant) utility theory, facilitates or promotes analytical modeling. This approach is advanced still further by plausible assumptions, such as periodicity and time-averaging, as have been employed in the present paper.

4.0 CONCLUSION

It is probably a fair statement that most economists believe their discipline too difficult or complicated to be approached through rigorous mathematical formulation. One prominent economist has printed this opinion—he observed that economics is an "intellectual exercise" that excludes "..the reality of economic life, which, alas, is not, in its varied disorder, suitable for mathematical replication." Galbraith (1987). My belief is that this conclusion is too pessimistic: We have over the centuries identified the salient factors of economic behavior, and having done so it is feasible, as in physics, to draw them together in mathematical frameworks or systems to explain economic life, and forecast the effects of economic policies and institutions.

In the present paper an attempt is made to demonstrate how the substantive mathematical approach can provide insights and advances that go beyond the capabilities of mainstream mathematical economics. First it was shown how the more-fundamental instant-utility methodology connected or related two widely-separated compartments of mathematical economics, Real Business Cycle Theory and Equilibrium Theory—a "connecting or relating" that may serve to move these theoretical compartments, and other compartments of economic theory, closer together within one consistent, overarching methodology, as prevails in physics. Later in the paper the instant-utility approach was employed to extend Ramsey's rule for saving to account for autonomic discounting and investment-risk discounting. The article concluded by addressing an important concern in social science—an essential difference between sociology and economics that must undermine or cloud their close cooperation. Here it was observed that the keystone "direct consumable utility" postulate of neoclassical mathematical economics was responsible for this difference—responsible, that is, by imposing value from outside the methodology, rather than from inside thereby reflecting real economic life. Adopting instant-utility of all human (mental and physical) activity-durations as basic theory places economics and sociology on the same endogenous plane, with the prospect of improved cooperation.

When we seek beneficent institutions and good governance we are influenced—and properly so—by the prevailing economic paradigm, with its strengths and deficiencies. Since economic science has this power in modern life, it is imperative to achieve a strong correspondence or connection between economic theory and economic reality. While there may be economists who believe that a satisfactory connection in this regard already exists, there can be no doubt, from the literature, that more than a few colleagues disagree. Economics science does, in fact, leave room for improvement, a statement that cannot be controversial. The science should move to a more fundamental basis. Besides the benefits to economics, conciliation could be achieved across all of science and philosophy—from physics and psychology to socioeconomics and the theories of justice and ethics. This would help guide domestic and international governance toward improving life on our planet.[41]

[41] Further discussion of this prospect is provided in "Does Uneven Expected Risk Promote Poverty and Instability?" (2003).

NOMENCLATURE

$a(t)$	Fraction of day occupied by production.
$b(t)$	Fraction of day occupied by consumption.
$\underline{b}$	Value of b on the bliss asymptote.
$\underline{B}$	Anticipatory feeling-state on the bliss asymptote.
Δa, Δb, Δc	Departure of a, b, and c from the bliss asymptote.
$\mathbf{C}_t$	Quantity of finished product consumed by society per day [GOOD/TIME].
$\boldsymbol{C_t}$	Per Capita hours per day in the consumption of consumables (TIME).
C_A, C_B, C_C	Amounts of consumables A, B, C, etc., consumed per day [GOOD/DAY].
$c(t)$	Fraction of day occupied by rest.
E	Instant utility experienced in anticipation of a plan of personal activity [PLEASURE].
E^i_k	E for individual i and plan of action k.
ΔE	Departure of E from the bliss asymptote.
$\Delta E_{t=0}$	ΔE at time $t = 0$.
$f(a, \kappa)$	Production of consumable per day for given a and κ [GOOD/TIME].
$\underline{f}_b$	Marginal productivity of direct labor per day on the bliss asymptote for a given b(t) and κ [GOOD/TIME].
$\underline{f}_\kappa$	Marginal productivity of capital per day on the bliss asymptote for a given b and κ [$TIME^{-1}$].
f_w	Expected occurrence probability of worldline w.
f^i_{kw}	f_w for individual i, activity plan k, and worldline w.
$\underline{g}_a$	Marginal productivity of labor per day on the bliss asymptote for a given a and κ [GOOD/TIME].
IU	Piecewise continuous process-of-knowing instant utility attending human activity [PLEASURE].
IU^i_{kw}	IU for individual i on worldline w of plan k.
$IU^i_C(t^*)$	IU^i for consumption only.
k	Activity plan (subscript).
$\boldsymbol{L_t}$	Leisure [TIME].
$L(t)$	Time-averaged instant utility of leisure [TIME].
$\underline{L}(t)$	L(t) on the bliss asymptote [TIME].
$l(t)$	Marginal instant utility of leisure [TIME]
$\underline{l}(t)$	l(t) on the bliss asymptote.
n	Number of intertemporal days.
Q.	Amount of finished product (consumable) consumed per day [GOOD].
ΔQ.	Amount of finished product given up [GOOD].
Q_A, Q_B, Q_C	Amounts of consumables A, B, C, etc., consumed per day [GOOD].
Q_μ.	Amount of consumable μ consumed per day [GOOD].
$\boldsymbol{R_t}$	Rest [TIME].
t, t^*, t'	Time.
UT	Total intertemporal utility
$U=U(t)=U(b)$	Time-averaged (per day) instant utility of consumption [PLEASURE].

$\underline{U}$	U on the bliss asymptote.
$\underline{U}^i_k$	U for individual i and activity plan k on the bliss asymptote.
u(b)	Marginal instant utility of consumptive activity (dU/db).
$\underline{u}$	u(b) on the bliss asymptote.
$\underline{\mathit{u}}$	Anticipatory *instant-utility* (anticipatory *feeling-state*) [INSTANT-UTILITY (feeling state)/GOOD]—which is *imputed* in the instant-utility methodology. (See footnote 31.)
U(x)	Time-averaged instant utility as a function of time-averaged rate of consumption, …changed to function of b(t) on page 26 (to be consistent with V and L).
u(x)	Marginal utility per unit consumable [INSTANT-UTILITYxTIME/GOOD]
$\Delta U_{t=0}$	Departure of U from the bliss asymptote at t = 0.
V(t) = V(a)	Time-averaged instant utility of productive activity.
$\underline{V}$	V(t) on the bliss asymptote.
ΔV, ΔU, ΔL	Departure of time-averaged productive, consumptive and leisure instant utilities from the bliss asymptote.
$\Delta V_{t=0}$,$\Delta L_{t=0}$, $\Delta L_{t=0}$	ΔV, ΔU, ΔL at t=0.
v(a)	Marginal instant-utility of productive activity.
w	Worldline—along which the individual forms an expectation, with certainty, of his or her personal activity time-line, in accordance with expected personal and environmental constraints.
X(t')	Instantaneous rate of consumption [GOOD/TIME].
x	Time-averaged rate of consumption [GOOD/TIME].

GREEK SYMBOLS

β	Postulated time-invariant instantaneous rate of consumption [GOOD/TIME].
$\delta_U(t')$	Delta-Function: 1.0 during consumptive activity, and 0.0 otherwise.
$\delta_V(t')$	Delta-Function: 1.0 during productive activity, and 0.0 otherwise.
Φ^{ic}_w	Constraint c(w) on worldline w for individual i.
κ	Capital amount [GOOD].
$\underline{\kappa}$	κ on the bliss asymptote.
Δκ	Departure of κ from the bliss asymptote.
$\Delta\kappa_{t=0}$.	Δκ at time t=0.
λ	Emotive mapping/discounting factor [$TIME^{-1}$].
$\underline{\lambda}^i$	λ on the bliss asymptote for individual i.
λ^i_w	λ on worldline w of individual i.
λ^i_{kw}	λ^i_w for plan k.
π	Event expected-occurrence probability.
ρ	Coefficient in exponential mapping/discount expression [e.g., $\lambda = \lambda_{t=0} \exp(-\rho t)$].
σ	Time constant (expectational) of the macro-economic system—linear approximation.

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