Quantum Type Indeterminacy in Dynamic Decision-Making: Self-control through Identity Management

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Abstract

The Type Indeterminacy model is a theoretical framework that uses some elements of quantum formalism to model the constructive preference perspective suggested by Kahneman and Tversky. In this paper we show that in a dynamic decision context type indeterminacy induces a game with multiple selves. In contrast with standard approaches all interaction is among contemporous potential selves. Indeterminacy alone suffices to deliver a theory of self management in terms of a Markov perfect equilibrium with identity as the state variable. The approach allows to characterize generic personality types.

"The idea of self-control is paradoxical unless it is assumed that the psyche contains more than one energy system, and that these energy systems have some degree of independence from each others"
(McIntosh 1969)

1 Introduction

We recently witness a renewed interest among prominent economic theorists for the issue of self-control and dynamic inconsistency in decision-making (see e.g., Gul and Pesendorfer (2001, 2004, 2005), Fudenberg and Levine (2006, 2010)). There exists a significant theoretical literature pioneered by Strotz (1955) dealing with various forms of dynamic inconsistency A large share of this literature has focused on inconsistency that arises because the individual does not discount the future at a constant rate. Some form of myopia is assumed (quasi-hyperbolic discounting) instead. Another approach to the planning problem is to model the individual in terms of multiple selves as first proposed in Peleg and Yaari (1973). Various ways to model those selves and interaction between them have been investigated. Fudenberg and Levine (2006) develop a dual self-model of self-control

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with a long-term benevolent patient self and a multiplicity of impulsive short-term selves - one per period. This particular structure allows them to write the game as a decision problem and they can explain a large variety of behavioral paradoxes. In this paper, we argue that the quantum approach to decision-making offers a suitable framework to the McIntosh's paradox of self-control because the indeterminacy of individual preferences precisely means multiplicity of the selves (the potential eigentypes). Our approach contributes to the literature on self-control by investigating a mechanism of self-control based on identity management that relies on the hypothesis of intrinsic indeterminacy. The technology for the transformation of identity reflects the dynamics of state transition under non-classical indeterminacy and the individual identity is the equilibrium outcome of interaction between the selves. An advantage is that we can capture some features of self-management not related to time preferences which have been the quasi exclusive focus of earlier works. Moreover we can connect to another branch of research related to identity and self-image extensively investigated in psychology (in particular within self-perception analysis see e.g., Bem (1972) for a review) and more recently in economics Benabou and Tirole (2004, 2011)

To many people it may appear unmotivated or artificial to turn to Quantum mechanics when investigating human behavioral phenomena. However, the founders of QM, including Bohr [**?**] and Heisenberg [**?**] early recognized the similarities between the two fields. In particular Bohr was influenced by the psychology and philosophy of knowledge of Harald Höffding. The similarity stems from the fact that in both fields *the object of investigation cannot (always) be separated from the process of investigation*.[1] Quantum Mechanics and in particular its mathematical formalism was developped to respond to that epistemological challenge(see the introduction in Bitbol (2009) for a enlighting presentation).

Under the last decade scholars from social sciences and psychology have contributed to the development of a "quantum-like decision theory by introducing (non-classical) indeterminacy (see e.g., Deutsch (1999), Busemeyer et al. (2006, 2007, 2008), Danilov et al. (2008), Franco (2007), Danilov et al. (2008), Khrennikov (2010), Lambert-Mogiliansky et al. (2009)). This line of research has shown itself very fruitful to explain a wide variety of behavioral phenomena ranging from cognitive dissonance to preferences reversal, the inverse fallacy or the disjunction effect.

The starting point for our approach is that we depart from the classical dogma that individuals are endowed with determined preferences and attitudes that motivate their behavior. Instead, we propose that the motivational underpinning of behavior is intrinsically uncertain i.e., indeterminate. It is

[1] in the words of Bohr "the impossibility of a sharp separation between the behavior of atomic object and the interaction with the measuring instruments which serves to define the condition under which the phenomena appears". In psychology investigating a person's emotional state affects the state of the person. In social sciences "revealing" one's preferences in a choice can affect those preferences: *"There is a growing body of evidence that supports an alternative conception according to which preferences are often constructed – not merely revealed – in the elicitation process. These constructions are contingent on the framing of the problem, the method of elicitation, and the context of the choice". [**?**] p.525.*

only at the moment the individual selects an action that a specific type is actualized. It is not merely revealed but rather determined in the sense that prior to the choice, there is an irreducible multiplicity of potential types. This idea, imported from Quantum Mechanics to the context of decision and game theory, is very much in line with Tversky and Simonson (Kahneman & Tversky, 2000), according to whom "There is a growing body of evidence that supports an alternative conception according to which preferences are often constructed not merely revealed in the elicitation process. These constructions are contingent on the framing of the problem, the method of elicitation, and the context of the choice".

The basic model of static decision-making with Type Indeterminte agents, the TI-model, is formulated in Lambert-Mogiliansky, Zamir, Zwirn (2009). As we consider dynamic individual optimization the TI-model induces a game among potential incarnations of the individual. We thus formulate the decision problem in terms of a game of several (one-period lived) players, the selves. They are linked to each other through two channels: 1. the selves share a common interests in the utility of the future incarnations of the individual; and 2. they are connected to each other in a process of state transition (which captures indeterminacy). We define a Markov Perfect Equilibrium among the selves where the state variable is the individual identity. In our model behavior affects future preferences (identity) and in particular a concerns for one's identity(self-image) arises endogenously. Choice behavior exhibits deviations from standard utility maximization. It is generally characterized by self-monitoring and can feature dynamic inconsistency. The model delivers some of the predictions of Benabou and Tirole's model of self-reputation. It also generates novel predictions on personality and behavior. The models unveils generic class of personality/behavior: on the one hand the little conflicted, weakly decisive but rather time consistent character. And on the other hand the highly conflicted, strongly decisive and time inconsistent character.

The paper is organized as follows. In the next section we expose some motivating puzzles and argue that our modelling is closely linked to the so called self-perception theory in psychology. Next we present a general model of optimization by type indeterminate agent. We illustrate main features in an example. Finally we discuss some links between our model and with the economic literature on self control and identity.

2 Motivating Puzzles

It appears that the idea that an individual's choice of action (behavior) determines her inner characteristics (preference, attitudes and beliefs) rather than (exclusively) the other way around has been present in people's mind throughout history and has been addressed in philosophy, psychologie in a variety of ways as well as more recently in economics.

Nevertheless the dominating view in particular in economics, is based on a postulat: individuals are endowed with an identity (preferences, attitudes and beleifs) that explain their behavior.[2] This postulate is hard to reconcile with a host of experimental evidence including at the more basic level of perception. It has long been known that the perception of pain is only partly a function of the pain stimulus. Zimbardo, Cohen, Weisenberg, Dworking and Firestone (1969) demonstrated that individuals who had volunterred to continue participation in an experiment using painful electric shocks reported the shocks to be less painful and were physiologically less responsive than individual who were given no choice about continuing. Valins and Ray (1967) conducted an experiment where snake-phobic subjects were presented pictures of snakes and were falsly reported that their heart beat was calm. Subsequently they exhibit significantly reduced fear for snakes. In another experiment, subject were cued to identify the same physiological arousal as either anger or euphoria (Schater and Singer 1962). Cognitive dissonance experiments in e.g., Carlsmith and Festinger classical experiment (1959) also show how behavior affects attitudes. For a systematic review of experimental evidences see Bem (1972). All these evidences led Weick (1967) to formulate the thesis that: "Attribution and attitudes may follows behavior and not precede it". Similarly Berkowitz (1968) remarks " We generally assume as a matter of course that the humans being act because of the wants arising from his undertsanding of the environment; In some cases, the understanding may develop *after* stimuli have evoked the action so that the understanding justifies but does not cause the behavior" (p.308).

Psychologists developed several theories to account for these exprimental facts. One of them in the theory of Cognitive Dissonance (Festinger) another is self-perception theory. As expressed by Bem (1972) self-perception theory is based on two postulates: 1. *"indivudual come to "know" their own attitude and other internal states partially by inferring them from observations of their own behavior and/or the circumstances in which behavior occurs.* 2. *Thus the indivudual is functionally in the same position as an outside observer, an observer who must necessarily rely upon those same external cues to infer the individual inner state." (*p. 2 Advances in Experimental Social Psychology 1972). Self-perception theory does not clearly give up the classical postulate. Nevertheless its own postulates are fully consistent with the hypothesis of (non-classical) indeterminacy which overturns the classical postulate of pre-existing identity, attitudes and preferences. With indeterminacy of the inner state, behavior (the action chosen in a decision situation, see below) shapes the state of preferences/attitude by force of a state transition process (see next section). Indeterminacy means intrinsic uncertainty about individual identity so the individual may not know his *own* attitudes, preferences and beliefs. And as in self-perception theory, it is by observing his own action that he infers (learns) his state (of beleifs and preferences). While self perception theory emphasises the similitude between outside observation and self observation, quantum decision theory puts emphasis on the fact that observation is structured. As recognized in self-perception theory inner states are not accessible without some training and instrument to measure them. To observe one needs an

[2] Of course it can evolve under the impact of well-identified influence e.g., education.

"appropriate descriptor" (Bem 1972 p.3). Such "descriptor" includes "cues" that can be manipulated to obtain widely different perceptions cf anger versus euphoria above. This is consistent with the most basic feature of indeterminacy namely that the property of a system does not pre-exist observation. Therefore different measurement instruments may give various incompatible but equaly true accounts of the same state. As we shall see this is also at the heart of the state transition process and delivers our theory of self-control.

3 The model

We shall describe the dynamic decision problem as a simple separable sequential differential game between the selves with the state variable identified as the identity(type) of the individual. The equilibrium concept we shall be using is that of Markov Perfect Equilibrium.

The kind of situations we have in mind is a sequence of (at least) two consecutive decisions. For instance Bob has just inherited some money from his aunt and the first decision is between buying state obligations or risky assets. The second decision situation is between a stay at home evening or taking his wife to a party. The two situations appeal to different type characteristics: the first to his preference toward risk: cautious (θ_1) risk loving (θ_2). the second decision situation appeals to his attitude toward others: (τ_1) egoistic versus generous/empathetic (τ_2). In each period the relevant eigentypes (see below for a definition of eigentype) e.g,. (θ_1, θ_2) are defined as the current short-run players whose play affect the future state(type) of the individual. We next develop the general theory and illustrate it in the above mentioned example.

3.1 The players

In each period the individual faces a Decision Situation (DS) A^t corresponding to the finite set of available actions in period t. We restrict the one-period players' strategy set to pure actions. The possible preferences over the profiles of actions (one action for each self) are denoted by $e^t_{M,i} \in E_M$ (where M defines a measurement operator). $E_M(a_1)$ are also called the eigenset of measurement M corresponding to the choice of action a_1(see Danilov et ALM 2008). We refer to the $e^t_{M,i}$ as the selves or the "eigentypes" of M.[3] They are the players of our game. The choice in DS A_t reveals (we herafater uses the term actualizes) the individual's preference or type. We say that DS A_t measures a type characteristics e.g., preference toward risk. A type characteristics takes different "values" e.g., cautious or risk loving which we refer to as the eigentypes.

In each period t the individual is represented by his state or type (we use the terms interchangeably), a vector $|s^t\rangle \in \mathbb{S}$, where $\mathbb{S}$ is a finite dimensional Hilbert space and the bracket $|.\rangle$ denotes a (ket)

[3] An eigentype is an eigenvalue of the operator.

vector in Dirac's notation which is standard when dealing with indeterminacy.[4] The eigentypes $e^t_{M,i}$ of M are associated with the eigenvector $\left|e^t_{M,i}\right\rangle$ of the operator which form a basis of the state space. The state vector can therefore be expressed as a superposition: $\left|s^t\right\rangle = \sum_i \lambda^t_i \left|e^t_{M,i}\right\rangle,\ \lambda_i \in \mathbb{R},\ \sum_i \left(\lambda^t_i\right)^2 = 1,$ where $e^t_{M,i}$ are the (potentials) selves relevant to the action set A_t. This formulation means that the individual does not have a single true preference, instead he is intrinsically "conflicted" which is expressed by the multiplicity of the potential selves. The coefficients λ_i, also called amplitude of probability, provides a measure of the relative strength of potential self $e^t_{M,i}$,i.e., of the probability that self $e^t_{M,i}$ will determine the behavior of the individual in DS A_t.

We assume throughout that there is common knowledge among the selves about the current state, the utility function of all selves and about the state transition process (see below).

3.2 Indeterminacy: Decision-making as a state transition process

In each period, the selves form intentions to play and eventually *one* action is taken by the individual. Decision-making is modelled as the measurement of the preferences (cf the revelation principle) and it is associated with a transition process from the initial state and (intended) actions to a new state.[5] The transition process features the minimal perturbation principle that defines a measurement operation (see Danilov and Lambert-Mogiliansky (2008)). The rules that govern the state transition process reflect the intrinsic indeterminacy of the individual's type or preferences. The transition process is actually more of a jump also called a collapse. It captures the von Neuman or (its stringent version Luder's) projection postulate: if the initial state is t and the chosen action is a_1 then the new state is the normalized projection of t onto the eigenspace belonging to a_1.[6]

Formally, a transition process is a function from the initial state and (intended) actions to a new state. It can be decomposed into an outcome mapping $\mu_{A^t} : \mathbb{S} \to \Delta A$ and a transition mapping $\tau_{M,a} : \mathbb{S} \to \mathbb{S}$. The first mapping defines the probability for the possible choices of action when an individual in state s is confronted with DS A. The second mapping $\tau_{M,a}$ indicates where the state transits as we confront the individual with DS A and obtain outcome a.

The standard Hilbert space formulation yields that if we, for instance, observe action a_1

$$\left|s^t\right\rangle = \sum_i \lambda^t_i \left|e^t_{M,i}\right\rangle \text{ and the state transits onto } \left|s^{t+1}\right\rangle = \sum_{j=1} \lambda'^t_j \left|e^t_{M,,j}\right\rangle$$

[4] The mathematical concept of a Hilbert space, named after David Hilbert, generalizes the notion of Euclidean space. It extends the methods of vector algebra and calculus from the two-dimensional Euclidean plane and three-dimensional space to spaces with any finite or infinite number of dimensions. The significance of the concept of a Hilbert space was underlined with the realization that it offers one of the best mathematical formulations of quantum mechanics. In short, the states of a quantum mechanical system are vectors in a certain Hilbert space, the observables are hermitian operators on that space, and measurements are orthogonal projections

[5] We use the term transition process but the "process" we consider is actually a jump from one state to another.

[6] We talked about eigenspace associated with eigenvalue "a" of a measurement operator if the eigenvalue is degenerated i.e., if several linearly independent vectors yield the same outcome of the measurement.

where $\lambda'_i = \frac{\lambda_i}{\sqrt{\sum_{k^t} \lambda_k^2 (s_k^* = a_1)}}$ where $\sum_{k^t} \lambda_k^2 (s_k^* = a_1^t)$ is the sum over the probabilities for the types who pool with $e^t_{M,,i}$ in choosing a_1. This is of course equivalent to Bayesian updating i.e., the state transition seems purely informational. The value of this more general formulation comes when dealing with a sequence of non-commuting DS. To see that the formal equivalence breaks down, we have to express $\left|s^{t+1}\right\rangle$ in terms of $\left|e^{t+1}_{N,i}\right\rangle$ where N is the new (non-commuting) measurement corresponding to $DS\ A^{t+1}$ and $\left|e^{t+1}_{N,i}\right\rangle$ are its eigenvectors.The eigenvectors of N also form a (alternative) basis of the state space. And this is where the earlier mentioned correlations between selves from different period enter into play. The correlations express the fact that the eigenvector of one operator can be written in terms of the eigenvectors of the other operator and vice et versa since both sets of eigenvectors form a basis of the state space.

These correlations captures the extent of overlap between the states.[7] In a classical world *all* distinct *atomic* states are orthogonal. So in a classical world we have that either the eigentypes are mutually exclusive: so for instance Bob is either be risk-loving or cautious. Or the eigentypes can be combined: Bob can be of risk-loving type *and* of the non-empathetic type. But this means that the type characteristics risk-loving is not be a complete characterisation i.e., not an atomic state. The novelty with indeterminacy is that type characteristics can overlap in the sense that they are non-orthogonal atomic states. For instance, in our example the risk-loving type and the cautious type are orthogonal but the risk-loving type and the non-empathetic type are not. Nevertheless, the three are complete descriptions of the individual i.e., they are atomic state. The risk-loving type overlaps the non-empathetic type. This means that if Bob is of the risk-loving type there is some probability that in his second choice he will reveal non-empathetic preferences and his type will be modified, he will no longer be of the risk-loving type. Instead, he will be fully characterized as a non-empathetic type. And, if tested again with respect to cautious/risk-loving characteristics, the state will transit again and he may end up as a cautious type. The correlations.are a measure of this overlap.

Let B_{MN} a basis transformation matrix that links the two non-compatible type characteristics M and N: $\left|e^t_{M,i}\right\rangle = \sum_j \delta_{ij} \left|e^{t+1}_{N,j}\right\rangle$ where δ_{ij} are the elements of the basis transformation matrix $\delta_{ij} = \left\langle e^{t+1}_{N,,j} \middle| e^t_{M,i} \right\rangle$. Collecting the terms we can write

$$\left|s^{t+1}\right\rangle = \sum_j \left(\sum_i \lambda'_i \delta_{ij} \right) \left|e^{t+1}_{N,i}\right\rangle = \sum_i \gamma_i^{t+1} \left|e^{t+1}_{N,i}\right\rangle .$$

According to Bohr's rule the probability for eigentype $\left|e^{t+1}_{N,i}\right\rangle$ (if the agent is confronted with DS A_{t+1} that measures type characteristics N) is

[7] "In physics, the expression transition probability generally refers to dynamical instability. Our use of the term is not directly related to instability rather we follow von Neuman's terminology. The transition probability between two states is meant to represent intuitively a measure of their overlapping. Actual transition from one state to another is triggered by a measurement." Beltrametti Cassinelli (1980).

$$TP : p\left(e_{N,1}^{t+1}\middle| s^{t+1}\right) = \left(\sum_i \lambda_i' \delta_{1i}\right)^2 \tag{1}$$

This is the crucial formula that captures the key distinction between the classical and the type indeterminacy approach. TP is *not* a conditional probability formula where the δ_{ij}^2 are statistical correlations between the eigentypes at the two stages. The probabilities for the N-eigentypes depend on the M-eigentypes' *play* in $DS\ A^t$. When no player chooses the same action, the choice of a^t separates out a single player (some $e_{M,i}^t$), the sum in paranthesis involve *one* term only. While when several players pool in choosing the same action the term in parenthesis involve several terms The player is a non-separable system with respect to A^t and A^{+1}.[8] As a consequence, the probabilities for the different players are given by the square of a sum, implying cross terms called interference effect, and not the sum of squares (as we would have in a classical setting). We note that since the amplitudes of probability can be negative number, the interference effect may be negative or positive.

We note that the state transition process is deterministic by the earlier mentioned minimal perturbation principle also or the von Neuman postulate which says that under the impact of a measurement a pure state transit into another pure state. In this paper, we are only dealing with pure types under the impact of A_t if we observe a_1^t we have

$$\left|s^t\right\rangle = \sum_i \lambda_i^t \left|e_{M,i}^t\right\rangle \text{ the state transits onto } \left|s^{t+1}\right\rangle = \sum_{j=1} \lambda_j'^t \left|e_{M,,j}^t\right\rangle = \sum_i \gamma_i^{t+1} \left|e_{N,i}^{t+1}\right\rangle.$$

that is $\left|s^{t+1}\right\rangle$ is a pure state. Yet, predictions on the outcome of A_{t+1} are probabilistic because of indeterminacy: $\left|s^{t+1}\right\rangle$ is a superposed state.

3.3 Utility

When dealing with multiple selves, the issue as to how to relate the utility of the selves (here the players) to that of the individual is not self-given. The problem is reminiscient of the aggregation of individual preferences into a social value. We adopt the following definition of the utility of self (or player) $e_{M,i}^t$ of playing of a_i^t and all the $-i$ other $t-$period players play $\mathbf{a}_{-i}^t$

$$U_{e_{M,i}^t}(a_i^t) + \delta_{e_{M,i}^t} \sum_{i=t}^{T} EU(s^{i+1}\left(a_i^t, \mathbf{a}_{-i}^t; s^t \middle| a^t = a_i^t\right))$$

where a^t denotes the actual play of the individual.

The utility for $e_{M,i}^t$ of playing a_i^t is made of two terms. The first term is the utility in the current period evaluated by the $e_{M,i}^t$. This term only depends on the action chosen by $e_{M,i}^t$. And the second term is the expected utility of the individual evaluated by the future selves conditional on $a^t = a_i^t$. The second term depends indirectly on the whole profile of action in the current period through

[8] This means that $\left|t_1^1\right\rangle$ cannot be written as a tensor product type composed of $\left|t^1\right\rangle_{GS(h_0)}$ and $\left|t^1\right\rangle_{GS(h_1)}$ or equivalently that the tensor product set $E(h_0) \otimes E(h_1)$ does not exist.

the state transition process $s^{i+1}\left(\mathbf{a}_i^t; s^t\right)$. The next period expected utility is $EU(s^{t+1}\left(\mathbf{a}^t; s^t\right)) = \sum_i \gamma_i\left(a_i^t \middle| \mathbf{a}^t\right) U\left(s^{i+1}\left(a_i^t; s^t\right)\right)$ where $\gamma_i\left(a_i^t \middle| \mathbf{a}^t\right)$ are the coefficient of superposition relevant to the next period future DS. It is the weighted sum of the utility of all the possible resulting types following $\mathbf{a}^t$, where the weights is given by updating according to TP. The possible resulting states $s^{i+1}\left(a_i^t; s^t\right)$ are expressed in terms of the eigentype relevant to A^{t+1} and the expected utility of period $t+1$ is calculated given the optimal choice of eigentypes $e_{N,j}^{t+1}$.

The current action profile only influences tomorrows state, the summation term can without loss of generality therefore be collapsed into a single term $EU^T(s^{t+1}\left(\mathbf{a}^t; s^t\right)) = \sum_{i=t}^T EU^*(s^{i+1}\left(\mathbf{a}^t; s^t\right))$. Which is the expected utility when all future selves in all periods play their equilibrium pure strategy.

Utility thus writes

$$U_{e_{M,i}^t}(a_i^t; s^t) + \delta_{e_{M,i}^t} EU^T(s^{t+1}\left(\mathbf{a}^t; s^t \middle| a^t = a_i^t\right)) \tag{2}$$

in each period the payoff relevant history of play is captured by the state variable representing the current identity.

There are two possible interpretations for the formulation in . We may define the utility of a self in a superposed state as proportional to its coefficient of superposition. In that case conditional on $a^t = a_i^t$, both utility in the separating state and utility in the superposed state is discounted by the coefficient of the initial superposition which can be deleted. Or we may assume some extent of bounded rationality: the self only cares for the cases when he survives and he always experiences utility in full. So neither utility under separation nore utility under superposition is discounted by the coefficient. This is not fully rational because it means that the selve although he understands that his choice of action affects his probability for survival (next periods' identity), he does not interest himself at all for the cases when he does not "survive". Survival "as such" is neutral.

3.4 The equilibrium

In each period, the current selves know the current state resulting from the previous actual play. We have common knowledge among the selves about the payoff function of all selves current and future. The payoffs are function of the actions and the current state as defined above. Together this means that we are dealing with a separable sequential game of complete information and that it seems most appropriate to restric ourselves to Markov strategies: a strategy for *a self* is a function $S \to A^t$ from the current state to the set of action available at period t. We shall accordingly focus on Markov Perfect Equilibria.

Definition 1 *A Markov Perfect Equilibrium of the game is characterized by* a_i^{t*} :

$$a_i^{t*} = \arg\max_{a_i \in A^t} U_{e_{M,i}^t}(a_i^t; s^t) + \delta_{e_{M,i}^t} \sum_{i=t}^T EU^*(s^{i+1}\left(\mathbf{a}^t; s^t\right)).$$

in all period t *and for all* $e_{M,i}^t$.

So we see that a self "only" needs to worry about his current utility and the expected utility value of his action via the resulting type. The equilibrium is found by backward induction. The equilibrium is defined in a rather standard way. The novelty lies in the technology for state transition process which captures indeterminacy. So in particular the state variable are the preferences themselves and they evolve in a non-monotonic way, reflecting the dynamics of the measuremnt operation and the correlations between non-commuting *DS*.

Although we know that a MPE exists in mixed strategies (cf theorem 13.1 Fudenberg Tirole 1991), we have no proof of existence for the case we restrict ourselves to pure strategies as we do here.

Remark 2 *We note that the equilibrium features two crucial elements of the Benabou and Tirole's construction. First, the chosen action actually impacts on who I am in the next period. Second, each self has a natural concern for resulting identity because it determines future utility.*

In Benabou and Tirole, the impact on identity is through learning In turn this follows from the hypothesis of type indeterminacy. It is captured in our game by defining the state variable as the individual type(identity).

Remark 3 *For the case all DS are commuting, the model is the one of an individual who does not know who he is and learns as he observes the actions he takes. Identity evolves through Bayesian updating as a function of actual play. With commuting DS there is no stake in "identity" (see example). The concern for identity arises exclusively as a consequence of the non-commutativity of the successive DS.*

This is important do we recover Benabou Tirole?

Remark 4 *For the special case with* $\delta_{e^t_{M,i}} = 0$ *for all selves in all periods, we are back in the simple decision making model of Lambert-Mogiliansky, Zamir et Zwirn. 2009.* $\delta_{e^t_{M,i}} = 1$ *is consistent with self-control equilibria because of the multiplicity of contemporaneous selves and the impact of actions on future identity. For* $\gamma_{e^t_{M,i}} \neq 0$, *the theory suggests a classification of individual traits and behavior as we show below.*

For the case the selves are short-sighted or unaware of the impact of action on the future type we have the basic model which has already been investigated. It was shown to explain anomalies in decision theory from cognitive dissonance to framing effect and preference reversal. For the case all but one self is unaware or short sighted we have a model with the dual structure typical for multiple-self models as in Fudenberg and Levine but the means of controlling the resulting type are very different. We leave to the future the investigation of the dual structure for aType Indeterminate player.

4 An illustrative example

We have one agent and we call him Bob. Bob faces two consecutive decisions DS1:$\{a_1, a_2\}$ and DS2: x_1, x_2.which do not commute. One story is as follows. Bob who just inherited some money from his aunt For the sake of concreteness, the first decision is between buying state obligations (a_1) or risky assets (a_2). The second choice decision is between a stay at home evening (x_1) or taking his wife to a party (x_2). The relevant type characteristics to DS1 have two values (eigentypes): cautious (θ_1) risk loving (θ_2). In DS2 the type characteristics has two values as well: (τ_1) egoistic versus generous/empathetic (τ_2).

An alternative story that bring us closer to Tirole and Benabou and to the literatur on self-control, is that DS1 is a choice between exercising and take an easy morning. DS2 is a choice between going to a movie with a friend and helping your mother with practical things. The idea is that both DS involve a choice between tempting simple (immediate) gratification and more sophisticated satisfaction.

We below define the utility associated to the different choices. An assumption that we make is that τ_2 experiences a high utility from x_2 while τ_1 experiences a low utility whatever he chooses. To put it differently, it is better for the agent to be of the τ_2 type. In our story the generous/empathetic type experiences a high utility when he pleases his wife. The egoist type experience a low utility from the evening whatever he does but always prefers to stay home. So it is better to be of the generous type.

We next provide the classical representation and solution to this decision problem.

4.1 Classical optimization

Let us first characterize the set of types. Since both type characteristics each have two values, Bob may be any of the following four types $\{\theta_1\tau_1, \theta_1\tau_2, \theta_2\tau_1, \theta_2\tau_2\}$ .The utility is described by table 1 and 2 below

Tab. 1

a_1	a_2
$U(a_1;\theta_1\tau_1) = U(a_1;\theta_1\tau_2) = 4$	$U(a_2;\theta_1\tau_1) = U(a_2;\theta_1\tau_2) = 2$
$U(a_1;\theta_2\tau_1) = U(a_1;\theta_2\tau_2) = 2$	$U(a_2;\theta_2\tau_1) = U(a_2;\theta_2\tau_2) = 3$

,

so only the θ value matters for the $a-$choice.

Tab.2

x_1	x_2
$U(x_1;\theta_1\tau_1) = U(x_1;\theta_2\tau_1) = 2$	$U(x_2;\theta_1\tau_1) = U(x_2;\theta_2\tau_1) = 0$
$U(x_1;\theta_1\tau_2) = U(x_1;\theta_2\tau_2) = 1$	$U(x_2;\theta_1\tau_2) = U(x_2;\theta_2\tau_2) = 8$

so here only the τ value matters for the $x-$choice.The tables above give us immediately the optimal choices:

$\theta_1\tau_1 \to (a_1, x_1)$	$\theta_2\tau_1 \to (a_2, x_1)$
$\theta_1\tau_2 \to (a_1, x_2)$	$\theta_2\tau_2 \to (a_2, x_2)$

Using the values in table 1 and 2, we note that type $\theta_1\tau_2$ achieves the highest total utility of 12. the lowest utility is achieved by $\theta_2\tau_1$.[9] While Bob knows his type, we do not. We know that "the population of Bobs" is characterized by the following distribution of types:

$\theta_1\tau_1 \to 0.15$	$\theta_2\tau_1 \to 0.35$
$\theta_1\tau_2 \to 0.35$	$\theta_2\tau_2 \to 0.15$

.

We note that the distribution of types in the population of Bobs exhibits a statistical correlation between the θ and τ type characteristics.

4.2 A TI-model of dynamic optimization

By definition the type characteristics relevant to the first DS1 is $\theta, \theta \in: \{\theta_1, \theta_2\}$. Subjecting Bob to the $a-$choice is a measurement of his θ characteristics. The type characteristics relevant to DS2 is $\tau, \tau \in \{\tau_1, \tau_2\}$ .Since the two DS do not commute we can write

$$|\theta_1\rangle = \alpha_1 |\tau_1\rangle + \alpha_2 |\tau_2\rangle$$

$$|\theta_2\rangle = \beta_1 |\tau_1\rangle + \beta_2 |\tau_2\rangle$$

where $\begin{pmatrix} \alpha_1 & \alpha_2 \\ \beta_1 & \beta_2 \end{pmatrix}$ is a rotation matrix $\alpha_1^2 + \alpha_2^2 = 1 = \beta_1^2 + \beta_2^2$. For the sake of comparison between the two models we let $\alpha_1 = \beta_2 = \sqrt{.3}$ and $\alpha_2 = -\beta_1 = \sqrt{.7}$.[10]

The TI-model has the structure of a separable sequential complete information[11] game (according to Fudenberg and Tirole's definition p (1991)) as follows. The set of players is $N : \{\theta_1, \theta_2, \tau_1, \tau_2\}$, the θ_i have action set $\{a_1, a_2\}$ they play at stage 1. At stage 2, it is the τ_i players' turn, they have action set $\{x_1, x_2\}$. There is an initial state $|s^0\rangle = \lambda_1 |\theta_1\rangle + \lambda_2 |\theta_2\rangle$, $\lambda_1^2 + \lambda_2^2 = 1$ with $\lambda_1 = \lambda_2 = \sqrt{.5}$. The transition process is defined by the rule for updating (von Neuman's postulate) and the correlations between players at different stages $(\alpha_1, \alpha_2, \beta_1, \beta_2)$ see sec. 3.2 above. So Bob is initially in (the superposed state $|s^0\rangle$ and assume that $a_1$is the optimal choice for θ_1 is while for θ_2 the optimal choice is a_2. If a_1 is played, then the state transits from $|s^0\rangle$ to $|s^1\rangle = |\theta_1\rangle = \alpha_1 |\tau_1\rangle + \alpha_2 |\tau_2\rangle$.

The utility of the τ players is as described in table 3:

$U_{\tau_1}(x_1) = 2$	$U_{\tau_1}(x_2) = 0$
$U_{\tau_2}(x_1) = 1$	$U_{\tau_2}(x_2) = 8$

and the utility of the θ-players is according to eq. (2)

$$EU(a_{\theta_1}; \theta_1, s^0) = U_{\theta_1}(a_{\theta_1}) + \gamma_{\theta_1} EU^* \left(s^1 \left(a_{\theta_1}, a_{\theta_{21}}; s^0\right)\right)$$

[9] Note that we here assume that we can compare the utility of the different types of Bob. This goes beyond standard assumption in economics that preclude inter personal utility comparisons. But is in line with inter personal comparisons made in the context of social choice theory.

[10] We remind that the coefficient of superposition are amplitude of probability which can take negative values and Bohr's rule calls for squaring them to obtain the probability.

[11] Maximal information TI-game are the non-classical counter-part of classical complete information games. But in a context of indeterminacy, it is not equivalent to complete information because there is an irreducible uncertainty. It is impossible to know all the type characteristics with certainty.

where we set $\gamma_{\theta_1} = \gamma_{\theta_2} = 1$. The numerical values of first term is given by Tab. 4:

$U_{\theta_1}(a_1) = 4$	$U_{\theta_1}(a_2) = 2$
$U_{\theta_2}(a_1) = 2$	$U_{\theta_2}(a_2) = 3$

.

To solve for the equilibrium, we proceed by backward induction to note that trivially since the "world ends after DS2", τ_1 chooses x_1 and τ_2 chooses x_2 (as in the classical model). Next, fix the strategy of eigentype θ_1, say he chooses a_1.[12] What is optimal for θ_2 to choose? If he chooses a_2, the (relevant) resulting state after DS1 is $|s^1\rangle = |\theta_2\rangle$. The utility, in the first period, associated with the choice of a_2 is $U_{\theta_2}(a_2) = 3$. In the second period Bob's type is $|\theta_2\rangle = \beta_1 |\tau_1\rangle + \beta_2 |\tau_2\rangle$ which, given what we know about the optimal choice of τ_1 and τ_2, yields an expected utility of $\beta_1^2 [U(x_1; \tau_1) = 1] + \beta_2^2 [U(x_2; \tau_2) = 8] = .7 + 8(.3) = 3.1$. The total (for both periods) expected utility from playing "a_2" for θ_2 is

$$EU(a_2; \theta_2, s^0) = 3 + 3.1 = 6.1$$

This should be compared with the utility, for θ_2, of playing "a_1" in which case he pools with θ_1 the resulting type in the first period is the same as the initial type i.e., $|s^1\rangle = |s^0\rangle = \lambda_1 |\theta_1\rangle + \lambda_2 |\theta_2\rangle$. The utility of playing a_1 is $U_{\theta_2}(a_1) = 2$ in the first period plus the expected utility of the second period. To calculate the latter, we first express the type vector $|t\rangle$ in terms of $|\tau_i\rangle$ eigenvectors:

$$|t\rangle = \lambda_1 (\alpha_1 |\tau_1\rangle + \alpha_2 |\tau_2\rangle) + \lambda_2 (\beta_1 |\tau_1\rangle + \beta_2 |\tau_2\rangle) = (\lambda_1\alpha_1 + \lambda_1\beta_1) |\tau_1\rangle + (\lambda_1\alpha_2 + \lambda_2\beta_2) |\tau_2\rangle .$$

The second period's expected utility is calculated taking the optimal choice of τ_1 and τ_2:

$$\left(\lambda_1^2\alpha_1^2 + \lambda_2^2\beta_1^2 + 2\lambda_1\alpha_1\lambda_2\beta_1\right) 1 + \left(\lambda_1^2\alpha_2^2 + \lambda_2^2\beta_2^2 + 2\lambda_1\alpha_2\lambda_2\beta_2\right) 8 = 0.042 + 7.664 = 7,706.$$

which yields

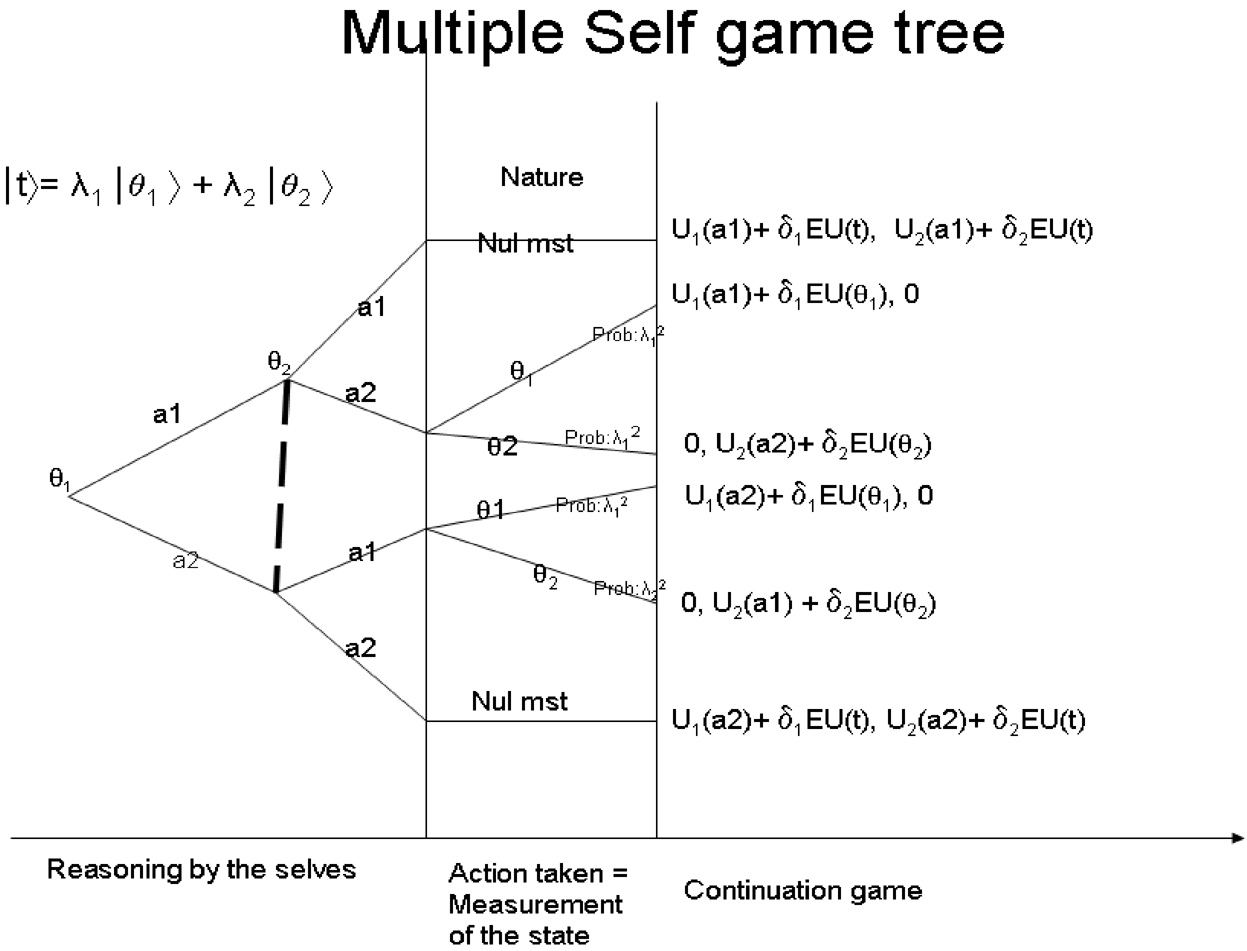
$$EU\left(a_1; \theta_2, s^0\right) = 2 + 7,706 = 9,706 > EU\left(a_2; \theta_2, s^0\right) = 3 + 3.1 = 6.1$$

So we see that because of the dynamics of indeterminacy captured by the state transition process, it is optimal for pure type θ_2 to forego a unit of utility in DS1 and play a_1 (instead of a_2 as in the classical model). There is a gain for θ_2 of preserving the superposition because the interference effect in the determination of the probability for τ_2 is positive.[13] It can also be verified that given the play of θ_2 it is indeed optimal for θ_1 to choose a_1. Hence, pooling on a_1 is part of a a Markov Perfect equilibrium.[14]

[12] We note that the assumption of "a_1" is not fully arbitrary since a_1 gives a higher utility to θ_1 than a_2. However, we could just as well have investigated the best reply of θ_1 after fixing (making assumption) the choice of θ_2 to a_2. See further below and note 12 for a justification of our choice.

[13] We note that if in this numerical example is the individual was to decide in DS A before he knew his θ type, he would also select a_1.

[14] The equilibrium need not be unique. The inner game is a coordination game. Since the preference of θ_2 are more in line with those of τ_2 (high correlation), it seems that a natural selection would lead to coordination on a_2 rather than a_1.



The multiple self game is illustrated in figure 5 where the utility when the self does not survive is zero. But utility is defined as in (2).We see that the concern for identity - that is of the impact on the state through the transition process, affects Bob's choice. The MPE exhibit self-management. The interpretation is that Bob's θ_2 type understands that buying risky assets appeals to his risk-loving self which makes him tense. He knows that when he is tense, his egoistic self tends to take over. So, in particular, in the evening he is very unlikely to feel the desire of pleasing his wife - his thoughts are simply somewhere else. But Bob also knows that when he is in the empathetic mood i.e., when he enjoys pleasing his wife and he does it, he always experiences deep happiness. So his risk-loving self may be willing to forego the thrill of doing a risky business in order to increase the chance for achieving a higher overall utility.

4.2.1 Generic class of behavior

The 2 types, two actions two period case allows to illustrate some basic comparative statics results. We must however keep in mind that in the 2X2 case, the interference effects are very significant by construction. We next assume, as in the example, that the interference effects favor the high utility option x_2 (and automatically reduced the probability for the low utility alternative) so we have

$$EU(\theta_2) < EU(\theta_1) < EU(t).$$

Generally, the propensity to be of the type who experiences the high second period utility are present in both θ_1 $(\alpha_2 |\tau_2\rangle)$ and in θ_2 $(\beta_2 |\tau_2\rangle)$. We have positive interference effects when those propensities tend to reinforce each other and increase the chance that the superposed individual will turn out to be of that type. We below discuss the case with negative interference effects and possible interpretation.

By definition the first DS is a measurement of type characteristics θ so we have the following:

$$U_{\theta_1}(a_1) > U_{\theta_1}(a_2) \text{ and } U_{\theta_2}(a_2) < U_{\theta_2}(a_1)$$

The first period selves have conflicting interests. We define a conflicted individual as an individual whose selves makes separating choice and a balanced individual an individual whose selves manage to agree on a common choice, we say that such behavior exhibits self-monitoring.

Proposition 5 *The model distinguishes between two classes of individuals: the conflicted individual is characterized by a MPE that is a separating equilibrium. It obtains whenever*

$$U_{\theta_1}(a_1) + \delta_1 EU(\theta_1) < U_{\theta_1}(a_2) + \delta_1 EU(t) \tag{3}$$

and

$$U_{\theta_2}(a_2) + \delta_2 EU(\theta_1) < U_{\theta_2}(a_1) + \delta_2 EU(t) \tag{4}$$

are falsified. Otherwise, the individual is balanced i.e., her inner equilibrium is characterized by pooling.

The inequalities **??** or 4 capture the selves' incentives.of choosing one's preferred action given that the other selves chooses his preferred first period action. When the inquality is falsified it is a dominating strategy for that self to choose his preferred first period action. Since we have conflict of interest, when both do not hold, the choices are separating. At the individual level this means that if questioned or invited to choose, she will promtly incarnate either one or the other self. She shows clear-cut preferences, determination. This also means that the first period action triggers state transition onto one of the eigentypes i.e., identity is modified. As a consequence, behavior will exhibit behavioral inconcistency (e.g., preference reversal). So this suggests that individuals who are quite extreme in their judgment and have clear-cut preferences also exhibit behavioral inconsistency. The identity of a conflicted individual keeps jumping from one period to another. The conflicted individual exhibits no self-control.

In constrast the balanced individual is characterized by selves who are willing to reach an agreement, they make a pooling choice. This occurs at the expenses of one of the selves who chooses to forego his preferred option. We referred to this as the exercise of self-control. The balanced individual has no clear-cut preferences, he retains the freedom to value options from different perspectives. The pooling equilibrium obtains when either **??** or 4 or both are true. We have pooling on a_1 for the case 4 is true. When both are true we could have pooling on either action. But since θ_1 is closer (highly correlated) to τ_2 and there is agreement on the advantage of identity τ_2, it is reasonable to expect pooling on a_1. For the case only **??** holds, the MPE yields pooling on a_2. Interestingly, although in two of three cases, the pooling MPE yields the "good" action a_1 in period 1, it is not always the case. Therefore our model is not equivalent to other models in the litterature that features a conflict between an impulsive self and a dominant forward looking self. Here we may have that the forward looking self when **??** does not hold chooses to refrain from his preferred action. This can capture the case when the individual feel that being too demanding with himself fires back. In the example, if the cautious type insists on being cautious, there is a 50% chance that the individual becomes a risk loving type who will have a high chance to be of the egoistic type which is costly for the individual since the will only get a low second period utility. We would like to emphasize that our model only features self control by *means of identity management*. In many models of reasonable-impulsive selves, the reasonable type takes action to limit the impulsive self's choice (e.g., Gul and Pesendorfer and Fudenberg and Levine). in this repect we stand close to Benabou Tirole 2011.

A pooling MPE, triggers no state transition. If the selves were pooling in all periods, the individual would simply behave as a an individual endowed with stable preferences. In our context, he behaves as an individual endowed with stochastic preferences with respect to the second choice. He does not qualify as inconsistent.

We could bring in some asymmetry by calling θ_1 the good type the more reasonable type.

Proposition 1 allows us to derive some simple comparative statics the inequality can be written: $U_{\theta_i}(a_i) - U_{\theta_i}(a_J) \leq (>) \gamma_i [EU(t) - EU(\theta_i)]$.

Proposition 6 *i. The larger γ_i, $i = 1, 2$ i.e., the more patient and or the more concerned by identity the selves, the more likely we are dealing with a balanced type.*

The interpretation is that γ_i captures the weight put on preserving identity t compared with becoming a (pure) θ_i type i.e., a one that falls for todays temptation. In our context the value of identity is directly related to the choice made by future selves. It is not an abstract additional concern. It is sufficient that one of the selves is patient to avoid the worse outcome?

Proposition 7 *ii. The larger the temptations (the larger $[U_{\theta_1}(a_i) - U_{\theta_i}(a_j)]$, more likely we the individual will turn out a conflicted type.*

The utility difference is the cost of resisting temptation for θ_1. The magnitude of that difference captures the degree of conflict between the selves. When the potential selves are very far apart in their valuations, they will have a hard time agreeing (pooling) and individual is likely to behave as a conflicted being.

Proposition 8 *iii. The larger* $EU(t) - EU(\theta_i)$ *for one of the selves the more likely the person will behave has a balanced it is not too costly the "good" type chooses to play* a_1,

$$U(a_2;\theta_2) > U(a_1;\theta_2) \ \ \text{but}\ U(a_2;\theta_2) + \gamma_1 EU(\theta_2) \leq U(a_1;\theta_2) + \gamma_1 EU(t) \tag{5}$$

We should be able to have result which relate to the structure of the initial state i.e., the coefficients of superpositions and the interference terms. .

Suppose instead that

$$EU(\theta_1) < EU(\theta_2) < EU(t)$$

We are dealing with a coordination game both θ-type prefer to preserve superposition.

We could have that $U(a_1;\theta_1) + \gamma_1 EU(\theta_1) > U(a_2;\theta_1) + \gamma_1 EU(t)$ so the weak type strongly prefers a_2 but $U(a_2;\theta_2) + \gamma_1 EU(\theta_2) \leq U(a_1;\theta_2) + \gamma_1 EU(t)$ so the θ_2 prefers pooling, then the individual is not so conflicted he chooses a_1 and remains superposed.

This means that we may have two consistent personality types, the consistently tempted ones (the moral type is weak experience low loss by behaving poorly and the consistently moral ones when the weak type . The weak ones do are not less balanced in this context.

4.2.1.1 Negative interference effect and higher dimension

If we instead had

$$EU(\theta_1) < EU(t) < EU(\theta_2)$$

the only pooling equilibrium would be on a_2 and the only condition would be that **??** is not verified. For technical reasons this never obtain in the 2X2 case but it may obtain in higher dimension. **Is that true?**

We have as in the example assumed that interference effect for good behavior are positive : what does it means?

It means that the two initial types interact reinforcingly to determine the probability for the good future high utility behavior of the individual. If the high utility behavior does not benefit from positive interference in the superposed state we may have that both types have higher future utility under separation. Under negative interference effect we never have any self control (in the sense of foregoing today's utility for tomorow's sake) and we always have dynamic inconsistency.

When do we have negative versus positive interference effects?

Basically it means that there is a value in indeterminacy or there is a cost. It depends on the correlation coefficient and thes on the observable pair we are considering.

Should we expect positive IE in context of self-control?

5 Discussion

There exists a vast theoretical literature pioneered by Strotz (1955) dealing with various type of time inconsistency (see also Machina, 1989, Sarrin and Wakker,1998). A large share of this literature has focused on inconsistency that arises because the individual does not discount the future at a constant rate. Some form of myopia is assumed (quasi-hyperbolic discounting) instead. Closely related to this paper is Benabou Tirole as well as articles by Fudenberg and Levine (2006). They develop a dual self model of self-control that can explain a large variety of behavioral paradoxes. In their model there is a long-term benevolent patient self and a multiplicity of impulsive short-term selves - one per period. This particular structure allows them to write the game as a decision problem. In contrast, we are dealing with a full-fledged game involving a multiplicity of simultaneous (symmetric) selves in each period. All selves are equally rational and care about the future expected utility of the individual. The dual self model is designed to capture the management of impatience and it has a strong predictive power. Interestingly, both the dual self model and the TI-model can show that (apparent) dynamic inconsistency may arise as a result of rational self-control. We trust that the quantum approach has the potential to capture self-management issues reflecting a wide range of conflicting interests within the individual. We aim at testing its predictive power along a variety of issues in future research.

The idea that people have incomplete information about who they are and learn from observing their own choices has also been addressed in economics e.g., Bodner and Prelec (2001) introduce the notion of diagnostic utility to capture the intrinsic value of self-image as an additional term of the utility function. Because people do not know their true identity they learn from their own behavior which is per se a valuable output from behavior. Recently, the informational argument has been formalized by Benabou and Tirole (2002, 2004, 2010). They depart from homo economicus by assuming instead 1. imperfect self-knowledge; 2. imperfect recall; 3. imperfect will power. With these three imperfections they can derive the value of self-esteem, self-monitoring behavior and reconcile with intertemporal inconsistency in behavior.

As with self-perception theory's postulates, we argue that there is a much more "economic way" of modeling most of those those phenomena by giving up the classical dogma of a pre-existing (deterministic) individual identity and replacing it by indeterminacy. Accordingly we do not postulate the existence of a true self that we ignore but instead the individual is represented by a state of potentials that is intrinsically multiple and contradictory. In a world of indeterminate agents, action truly shapes the individual's identity because actions have a real impact on the state. Therefore actions aimed at shaping one's identity are fully justified from an instrumental point of view. In particular there is no need to add any additional concerns for self-image (as in Benabou and Tirole), or diagnostic utility (as in Prelec). All decision situations have elements of self-monitoring which may or may not determine the choice of action. Reconnecting to Benabou and Tirole: Indeterminacy implies imperfect knowledge because of intrinsic uncertainty: there is no "one truth" to be learned but created. Indeterminacy implies imperfect recall because indeed there is nothing that is true forever. The state keeps transiting with the action taken so yesterday's correctly inferred information about oneself may simply not be valid tomorrow. Indeterminacy implies "imperfect will power" because it implies multiple selves both simultaneously (multiplicy of potentials) and dynamically therefore there are necessarily conflicting desires and issues of self-control and self monitoring.

(QJE 2011 805-855)Identity is vA,where A is a stock and it evolves with investment and v is beliefs and it volves through inference. But actually type or deep preferences defined as v. But they do compstatic on invstment inA!The equivalent to our state transition process is the beleifs formation or more precisely the malleability of belief through action because for action to impact it requires forgetting about identity. Conditional expectation formed on the basis of previous action is far from a clean process. As they write "the malleability may reflect the repression of deeds or viewed as uninformative for attribution reasons (manipulability to excuse oneself). elements of bounded rationality if the reason for why you forget is that you did not like, then it is not neutral as treated in the model. The supply side is self inference and the demand side is self-esteem, anticipatory utility and imperfect self control. Good identity convention.

They also are concerned with separating and pooling but for other reasons.

In our case the cost is evaluated by the selves not the uninformed individual. But we could see it as two selves v_L and v_H.

5.0.1.2 Discuss correlation: "When contemplating choices,they then take into account what kind of a person each alternativewould"

make them"and the desirability of those self-views—a form of rational cognitive dissonance reduction."QJE 806-807

" Two related forms of behavioral instability are history dependence and nonmonotonicity. When a person has been induced to behave prosocially or selfishly, or just provided with signals presumed to be informative about his morality, *his choices in subsequent, unrelated interactions are significantly affected*. Moreover, this reaction *sometimes amplifies* the original manipulation, and is *sometimes in opposition* to it. The well-known "footinthe door" effect, for instance, documents howan initial request for a small favor (which most people accept) raises the probability of accepting costlier ones later on; similarly, a large initial request (whichmost peoplereject) reduces later willingness togrant a smaller one (see DeJong 1979).they are non-individual they can be biological or socially generated." QJE 2011 p 810,

"The patterns of behavior described in this section are not easily accounted for by existing models. The choices of agents with altruistic, joy-of-giving, reciprocity or fairness concerns will (under anonymity) consistently reflect these stable preferences, and not exhibit the“Jekyll andHyde”reversals andpathdependencies commonly seen in both lab and field" QJE 2011 p. 812

Contemplating taboo issues may force upon a very costly collapse where superposition is highly valuable.

References

[1] Barkan, R., and Busemeyer, J. R. (2003). Modeling dynamic inconsistency with a changing reference point. *Journal of Behavioral Decision Making*, 16, 235-255.

[2] Busemeyer, J. R., Weg, E., Barkan, R., Li, X., & Ma, Z. (2000). Dynamic and consequential consistency of choices between paths of decision trees. *Journal of Experimental Psychology*: General, 129, 530-545.

[3] Busemeyer J.R., Wang, Z. and Townsend J.T. (2006) "Quantum Dynamics of Human Decision-Making" *Journal of Mathematical Psychology* 50, 220-241.

[4] Busemeyer J. R. (2007)"Quantum Information Processing Explanation for Interaction between Inferences and Decisions." Proceedings of the Quantum Interaction Symposium AAAI Press.

[5] Busemeyer JR, Santuy E. ant A. Lambert-Mogiliansky (2008a) "Distinguishing quantum and markov models of human decision making"in Proceedings of the the second interaction symposium (QI 2008), 68-75.

[6] Busemeyer J. and A. Lambert-Mogiliansky, (2009) "An exploration of Type Indeterminacy in strategic Decision-making" in Quantum Interaction, Springer LNAI 5494, p.113-128.

[7] Cubitt, R. P., Starmer, C., & Sugden, R. (1998). Dynamic choice and the common ratio e¤ect: An experimental invesigation. *Economic Journal*, 108, 1362-1380

[8] Danilov V. I. and A. Lambert-Mogiliansky. (2008). "Measurable Systems and Behavioral Sciences".*Mathematical Social Sciences* 55, 315-340.

[9] Danilov V. I. and A. Lambert-Mogiliansky.(2008) " Decision-making under non-classical uncertainty"in Proceedings of the the second interaction symposium (QI 2008), 83-87.

[10] Danilov V. I. and A. Lambert-Mogiliansky. (2009) " Expected Utility under Non-classical Uncertainty" *Theory and Decision* 2010/68 25-47.

[11] Deutsch D. (1999). Quantum Theory of Propability and Decisions. Proc. R. Soc. Lond. A 455,3129-3137.

[12] Franco R., (2007) "The conjunction Fallacy and Interference Effects" arXiv:0708.3948v1

[13] Franco R. (2008) " The inverse fallacy and quantum formalism" in Proceedings of the Second Quantum Interaction international symposium (QI 2008), 94-98.

[14] Fudenberg and Levine (2006) "A Dual Self Model of Impulse Control," *American Economic Review*, 96: 1449-1476, 2006.

[15] Fudenberg and Levine (2010) " Timing and Self-Control" working paper.

[16] Gul, F. and W. Pesendorfer [2001]: "Temptation and Self Control," Econometrica, 69: 1403-1436.

[17] Gul, F. and W. Pesendorfer [2004]: "Self Control and the Theory of Consumption,"Econometrica, 72, 110-158.

[18] Gul, F. and W. Pesendorfer [2005]: "The Revealed Preference Theory of Changing Tastes" Review of Economic Studies.

[19] Hey, J. D., & Knoll, J. A. (2007). How far ahead do people plan? Economic Letters, 96, 8-13.

[20] Khrennikov A. (2010), Ubiquitous Quantum Structure - From Psychology to Finance, Springer.

[21] Kirsteiger G;, L. Rigotti and A. Rustichini (2006) "Your Morals Might be Your Moods" *Journal of Economic Behavior and Organization* Vol 59/2, 155-172.

[22] A. Lambert-Mogiliansky, Shmuel Zamir and Hervé Zwirn (2009) "Type indeterminacy - A Model of the KT(Khaneman Tversky)- man" *Journal of Mathematical Psychology* 2009 Vol 53/5 p. 349-361

[23] "Foundation of Human Society" (1969) University of Chigago Press

[24] Maskin and Tiroole (2001) "Markov Perfect Equilibrium" *Journal of Economic Theory* 100, 191-219.

[25] A. Lambert-Mogiliansky(2010)"Endogenous preferences in games with Type-Indeterminate Players" AAAI Press Menlo Park, FS 10-08, 70-77.

[26] La Mura P. (2005). "Correlated Equilibria of Classical strategies with Quantum Signals" *International Journal Of Quantum Information,* 3, 183-188.

[27] La Mura P. (2008) "Prospective Expected Utility"in Proceedings of the the Second Quantum Interaction International Symposium (QI 2008), 87-94.

[28] Machina, M. (1989). Dynamic inconsistency and non-expected utility models of choice under uncertainty. Journal of Economic Literature, 27, 1622-1668

[29] Peleg B and M yaari (1973) "On the Existence of a Consistent Course of Action when Tastes are Changing" Review of Economic Studies vol 40/3 pp, 391-401.

[30] R.H. Strotz (1956) "Myopya and Time Inconsistency in Dynamic Utility Maximization" *Review of Economic Studies* Vol 23/3 165-180.

Example

Consider the following example: $t = 2,\ K = 1, N = \left\{1^1, 2^1, 1^2, 2^2\right\},\ A = \{a_1, a_2\},\ B = \{b_1, b_2\}$ and the two first period players are described by the following utilities: $U\left(a_1; 1^1\right) = 2, U(a_2; 1^1) = 3$ and $U\left(a_1; 2^1\right) = 8,\ U(a_2; 2^2) = 2$. The two second period players have utilities $U\left(b_1; 1^2\right) = 3, U(b_1; 2^2) = 2$ and $U\left(b_2; 1^2\right) = 2, U(b_2; , 2^2) = 7$. The individual is initially represented by $|s\rangle = \lambda_1 \left|1^1\right\rangle + \lambda_2 \left|2^1\right\rangle$, to complete the description we need the correlations:

$$\left|1^1\right\rangle = \alpha_1 \left|1^2\right\rangle + \alpha_2 \left|2^2\right\rangle,\ \left|2^1\right\rangle = \beta_1 \left|1^2\right\rangle + \beta_2 \left|2^2\right\rangle$$

If both period one players pool to play a_1 indeterminacy is preserved, the composition of the family is unchanged. While if player 1 plays a_1 and player 2 a_2, the family's composition is changed.

Write in terms of the general formula for utility.

In order to analyze the game we proceed by backward induction. The second period players' utility does not directly depends on the first period play. It depends on the type of the player. 1^2 chooses b_1 and 2^2 chooses b_2 which yields $U\left(b_1; 1^2\right) = 3$ respectively $U(b_2; , 2^2) = 7$. In particular in player 1^1 actually plays a_2 player 2 exits and the family collapses on $|F'\rangle = \left|1^1\right\rangle$. The total utility is $3 + \alpha_1^2 3 + \alpha_2^2 7$ while if 1^1 plays a_1, the total utility is $2 + \lambda_1^2\left(\alpha_1 + \beta_1\right)^2 \cdot 3 + \lambda_2^2\left(\alpha_2 + \beta_2\right)^2 \cdot 7$ which can be larger than $3 + \alpha_1^2 3 + \alpha_2^2 7$. So player 1^1 cares about what 1^2 wants to play and it wants to do the same in order to preserve indeterminacy.