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Mainstream economics is grounded on a notion of individual decision conceived in a rather restrictive way. Even if an actor may be unconscious of the choice procedure he follows, a decision is assumed to result from a rational deliberation process. Such a model applies to a voluntary choice between available actions in order to select the implemented one. This notion is more restrictive than the one used in cognitive sciences, especially in neurosciences. Here, a decision is analyzed as the selection of some item in a predefined set, whatever the selection process involved. In that perspective, the field of decisions includes sensorial perceptions as well as body movements (Berthoz, 2003). However, in perception contrary to economics, a choice concerns an objective magnitude and can be compared to a correct answer known by the modeller. The narrow definition will nevertheless be considered in the present paper in order to compare the usual processes grounding deliberate choices.

In economics, the study of a decision taken by some actor led to sophisticated theories modulated by the various decision contexts where they apply. Intertemporal decision is related to a sequence of similar actions implemented by the actor on a finite or infinite sequence of periods. Choice under uncertainty is related to a single decision against nature when the future states of nature are badly known or even unknown for the actor. Strategic choice is related to a decision the actor has to take against other ones who interact with him, although with different aims. Social choice is related to an actor who takes a decision in conjunction with some other actors all sharing a common objective. These choice processes are formalized with a similar kit of concepts and tools, but become adapted to the strong or limited form of rationality of the actor.

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Classical or more original choice processes were systematically experimented on humans or animals in laboratory conditions during the thirty last years. Two successive streams gave rise to two hybrid disciplines relying on different investigation techniques. *Psycho-economics* rests on actors' observation and introspection in order to study the mental processes which govern their decisions. It aims at revealing how mental states are shaped and combined in order to make a decision. *Neuro-economics* examines by brain imaging the brain processes which take place when an actor is involved in some decision. It aims at finding out how the brain areas are activated and linked in the reasoning operations leading to a decision[1]. The first school was celebrated by the Nobel prize attributed to D. Kahneman while the second school nervously waits for the same prize.

The present paper examines some epistemological problems raised by these two approaches, especially the second. In section 1, an ontological view details the four organization levels which are involved in economic analysis. Section 2 describes the concepts specifically used at each level and examines their measurement methods. Section 3 compares the models proposed at each level and assesses the relevance of an autonomous description of each. Section 4 distinguishes two modalities by which variables associated to two successive levels may be related. Section 5 studies the bridge principles linking similar concepts at two levels and their main properties. Section 6 is devoted to the links between mechanisms proposed at different levels and acting in one way or both. In section 7, some methodological differences between disciplines concerning model evaluation are stressed. Section 8 is concerned by applications of the former analysis to prediction and prescription while section 9 concludes.

1 Organization Levels

Four successive organization levels are generally considered in economics, which define three layers linking them sequentially. Each level is symbolized by some basic entity which characterizes the activity taking place on it. The *neural level* deals with the mechanisms of the brain, especially the 'neural signals' which are emitted by it. The *mental level* is concerned with the reasoning modes acting on 'mental states' which characterize an actor. The *behavioural level* is related with the actor's observable behaviour for-

[1] Especially in the 'behavioral economics' literature, what is meant by neuro-economics gathers what is called here neuro-economics as well as a part of psycho-economics. Surveys are provided by Glimcher (2003), Glimcher & Rustichini (2004), Camerer et al. (2005), Glimcher et al. (2008), Sanfey et al. (2006), Montague (2007), Clithero et al. (2008), Schmidt (2010), special issues of reviews by Rustichini (2005), Stern (2007), Bonnano et al. (2008), critical comments by Rubinstein (2008), Harrison (2008), Bernheim (2009).

med of the 'actions' he implements. The *social level* is interested by various 'collective phenomena' such as social organizations or institutions. Considered in the reverse way, these levels are concerned with deeper and deeper foundations for all economic phenomena which arise at a social or individual level, especially the agents' decisions.

However, the four levels are not articulated along a simple and continuous criterion leading from the most elementary to the most sophisticated one. The neural, behavioural and even social levels appear as 'physical' levels which describe a natural nested organization. More precisely, the brain is an organ which is assumed to govern the individual's behaviour while the individual actor is the motor of social life. Of a different type, the mental level is a 'psychical' level which introduces another dimension in the preceding hierarchy. Since mental states are produced by the brain and related to each individual, the mental level is situated by convention between the neural and behavioural ones. Of course, mental states may refer to the social level as well, but they remain attached to individuals and are assumed to have no social support. In any case, mental states will be considered as 'naturalistic' in the sense that they are objectively grasped by the modeller.

Between two successive levels, a layer is intended to check the relations between corresponding entities and properties. These layers are taken into account by three disciplines which develop their own language and use their own methods. *Neuro-economics* justifies the actors' mental states by relating them to the neural signals emitted by the brain. *Psycho-economics* analyzes the actors' actions by combining the mental states acting as motivating reasons. *Eco-economics* examines how social phenomena are obtained by the conjunction of individual actions, whether intentional or not. If eco-economics is just the original economic discipline, psycho-economics appeared more than thirty years ago while neuro-economics is only fifteen years old. Since the paper is essentially interested in decisions, the social level will not be further considered.

For each layer, the lower level appears as the 'microscopic' one and the upper level as the 'macroscopic' one. A methodological assumption assumes that each layer is autonomous in the sense that interactions take place only for adjacent levels. Any macroscopic phenomenon, sometimes interpreted as an 'emergent phenomenon' (Walliser, 2009), is explained as much as possible by corresponding microscopic factors. However, some shortcuts may be at work, which directly relate characteristics of the inferior level to characteristics of a non contiguous superior one. For instance, as concerns reflex actions, neural signals may influence individual actions without any interpretation by mental states. Likewise, some individual mental states may shape collective norms without any influence of individual actions. However, as concerns decision, the basic postulate asserts that choices depend only on mental states and mental states on brain activity.

2 Concepts at Each Level

At the neural level, the main concepts correspond to neural signals emitted by the brain (electric currents, chemical exchanges, blood pressure). Some experiments look rather intrusive, especially electric stimuli or oxytocine absorption. But most of them content with observing the activity of brain areas, especially fMRI (functional magnetic resonance imaging). The brain is anatomically divided into a set of areas and sub-areas which admit conventional frontiers. The located variable just reflects the 'firing' of such an area and eventually the intensity of this firing. Gathered in very artificial conditions for the actor, the primary data are fragile and noisy and need a lot of repetitions. They are submitted to a statistical (and diversely biased) pre-treatment, which transforms them into a synthetic image acting as a 'stylized fact'. More recently, richer observations concern, in a dynamic perspective, circuits which are established between some areas.

At the mental level, the concepts are various properties of mental states expressed by the actors. The basic taxonomy distinguishes beliefs and preferences of an agent on one side, intended actions on the other. They are themselves simplified and decomposed into different concepts independently measured. For instance, if a belief may be reduced to the probability of occurrence of some event, a preference may be reduced to the utility of some effect. More recently, emotions were introduced and categorized in an heterogeneous way: anger, joy/pain, fear, disgust, shame and surprise (Hume, 1739-40; Damasio, 1994; Elster, 1999). The mental states associated to some choice are mainly measured by direct testimony of the actors. In some circumstances, the actors may even make explicit the mental mechanisms leading to some choice. But measures may be biased since the actors have no incentive to express them faithfully, even if a voluntary bias may be costly if a decision becomes really implemented.

At the behavioural level, the main concepts concern the choices implemented by some actor. By commodity, some virtual actions only declared by the actor may nevertheless be treated as true actions. Several kinds of actions are considered, especially informational ones (aiming at obtaining some information from various sources) and operational ones (aiming at modifying physically the actor's environment). The only problem is to treat together the parallel or sequential actions resulting from a same decision process. Actions are generally observed without bias by the observer, but they may be biased by the actor in order to hide his intentions. Note that, at an intermediate level between neural signals and actions, some other physical manifestations are sometimes observed. They appear as 'physiological signals' emitted by the body such as eye movements, blood pressure, transpiration or otherwise reaction time.

The modeller gathers his observations in real life, but obtains them more often in laboratory experiments. The last imply partial isolation of

actors, manipulation of some external factors and control of actors by prior instructions. They need to be repeated in conditions which are either similar or with controlled differences. Data are frequently gathered at different organization levels by observing simultaneously brain images, declared mental states as well as chosen actions. Experiences concern individual choices or games, but need to be simple enough in order not to mix too much factors. Since observations remain costly, especially for brain images, experiences may be reduced to small populations. Moreover, observations are more or less controlled by the actor according to the level: 'the actors may tell stories, but the brains do not lie'. Finally, in many publications, the experimental conditions are only roughly described, primary data are absent and treatment of data stays opaque (Harrison, 2008).

3 Mechanisms at Each Level

At the neural level, there are no precise models of the way the brain functions in order to produce a decision. The modeller only assumes that the brain areas act as 'modules' which interact together by exchanging signals. But the precise work realized by each area as well as the relations between areas are not clearly conceptualized. It is just assumed that some hierarchy holds in the brain by which upper modules control lower ones with some feedbacks. Curiously enough, some economic models were recently proposed in order to simulate mechanisms taking place in the brain (see Brocas & Carrillo, 2008). They attempt to describe the coordination devices acting between decentralized units of the brain. They try to reproduce the learning process followed by the brain when receiving outside information. But these analogical models proposed by 'neurocellular economics' appear as highly speculative and cannot be directly tested.

At the mental level, the modeller represents the decision process as a reasoning process involving rationality assumptions. Classical logic already describes how an actor uses deductive reasoning in order to infer consequences from assumptions. Epistemic logic shows how an actor deals with his beliefs, especially how he structures and revises them. Belief revision is pivotal since several reasoning modes are shown to be isomorphic to it: non monotonic reasoning, abductive reasoning, conditional reasoning (Walliser, Zwirn & Zwirn, 2003). Any reasoning process is spontaneously stated in a syntactic framework by introducing belief operators acting on propositions. It is represented in a purely mechanical 'algorithmic' way or in a more interpreted 'computational' way (Marr, 1982). Conversely, the reasoning process is expressed in semantics by introducing accessibility relations on a set of possible worlds. Psychologists precisely describe it in this way, by considering that actors proceed by simple operations on mental maps (Johnson-Laird, 1994).

At the behavioural level, classical analysis introduces mental states too, but considered now as unobservable. The decision process states that any actor combines three mental states (opportunities, beliefs, preferences) according to rationality principles of two kinds. Instrumental rationality deals with adjustment of opportunities to preferences while cognitive rationality deals with adjustment of beliefs to information (Walliser, 1989). More precise principles are moreover stated: independence of beliefs and preferences, no self-control on beliefs, commensurability of utilities. Some sets of decision axioms lead to decision rules (often maximizing ones) specifically adapted to each choice context. When these rules are assumed to be satisfied, the mental states are just 'revealed' from the past observed choices as hidden variables. But revelation is an abductive process which is difficult to implement for the modeller and even more for the actor. The revealed mental states are not unique, look instable and lack robustness to context.

An epistemological debate wonders if the behavioural level can be considered as autonomous or not, with reference to the data taken into account (Hausmann, 2008). An 'integrist position' states that studying choice at the sole behavioural level is not restrictive. It argues that the usual decision process is agnostic about the mental and neural foundations of decision. It asserts that introducing low level variables is not fruitful since they are already considered at the behavioural level. This position is endorsed by all classical economists convinced by the sufficiency of the 'revelation approach' (Gul & Pesendorfer, 2008). An 'ecumenical position' states that the decision process may benefit from observations at the mental and neural levels. It argues that decision at the behavioural level is tautological and cannot be independently tested. It asserts that inferior levels introduce some effects which are not perceptible at the behavioural level. This position is adopted by many psycho-economists and neuro-economists who accept to consider 'observed' mental states rather than hidden ones only.

4 Linking Two Levels

The modeller tries now to explain some well-defined phenomenon situated at a precise level. He may simply look for an 'intra-level explanation' relating the phenomenon to causes at the same level. But he looks more frequently for an 'inter-level explanation' relating the phenomenon to causes at the inferior level. This last operation can again be done in two ways, either directly or indirectly, the second being a decomposition of the first. In a direct way, a macroscopic phenomenon is just related by a 'link principle' to a set of microscopic factors able to explain them. In an indirect way, each macroscopic variable is first assimilated to a combination of

microscopic ones by means of a 'bridge principle'. With respect to this principle, a model relating microscopic variables is then transformed into a model relating macroscopic ones. The direct way is described in the following of this section and the indirect way in the next two sections.

In psycho-economics, the direct way is at work when an implemented action is directly related to some declared mental states. For instance, when an actor bets on some horse running a race, the modeller observes on what horse he engaged money and registers his knowledge of each horse. Since the stakes are precisely stated, he assumes that the betting actor chooses only according to his beliefs about horses. These beliefs result from past experience and reading of newspapers, and can approximately be stated by the actor. Likewise, when an actor chooses a cooperative or non-cooperative action in a public good game, the experimenter observes the chosen action and asks the actor about his motivations. Since information is almost complete about the situation at hand, he assumes that the actor chooses only according to his preferences. These preferences are harder to make explicit since they contain elements of fairness or symbolic utility.

In neuro-economics, the direct way is at work when a declared mental state is directly related to a collection of brain signals. For instance, when projecting an image of some conflict to an individual, the experimenter gathers simultaneously the description given by the actor and the brain areas which are firing. He assumes that the active brain areas are part of an explanation of the actor's belief or at least a support for it. However, only the conscious perception of the image is taken into account contrary to some unconscious printing. Likewise, when putting the hand of some individual into hot water, the modeller gathers simultaneously the pain experienced by the actor and the brain areas which are firing. He assumes that the actor's declared utility is explained by the active brain areas or at least correlated with them. However, the pain felt by the actor is very crude and contextual, hence hard to express on some objective scale.

The last experiments have to be distinguished from those already achieved in the XIXth century by Fechner or Helmholz. The 'psycho-physical' literature introduces an 'influence principle' which relates the physical intensity of some stimulus and the psychological sensation induced on the same individual. For instance, it relates the psychological assessment of perceived noise to the physical intensity of the noise through a logarithmic function. If the psychological sensation can be assimilated to a mental state, it is related to outside physical stimuli and not to inside brain signals. However, any neuro-economic experiment needs an external stimulus which acts both on brain signals and on mental states. A direct influence principle is at work in the second effect. An indirect influence principle can be obtained by combining the first effect with a bridge principle (linking brain signal and mental state).

5 Bridge Principles between Concepts

A bridge principle relates two concepts intended to express a same fact at two successive levels, however with different structures and terminologies. It is formally expressed by a function which links some macroscopic variable to a set of microscopic ones. A bridge principle is 'univoque' when any combination of microscopic values results in a unique macroscopic value ('supervenience'). It is 'biunivoque' when any macroscopic value is obtained by a single set of microscopic ones. A bridge principle is 'theoretical' when the macroscopic concept is just defined as a combination of microscopic ones. It is 'empirical' when the corresponding variables can be measured independently at each level and compared. In the last case, the bridge principle may represent some explaining mechanism working vertically between two levels. It is 'ascendant' when explanation goes from the lower level to the upper one without feedback (and 'bilateral' if not). It is 'synchronic' when the related variables are all evaluated at the same period without delay (and 'diachronic' if not).

In psycho-economics, the main bridge principle relates biunivocally an intended action to an implemented one. This principle is empirical when both modalities of actions can be observed by the modeller. Precisely, psychologists study conditions under which an intended action is implemented either with some deviation or is not implemented at all. Of course, these conditions may be taken into account in the deliberation process and modify the action intended at first glance. More profound factors may even blockade unconsciously the realization of an adapted action. Besides, the most usual bridge principles relate the revealed mental states to the declared ones. They are biunivoque by construction, but stay purely theoretical since the revealed mental states are computable but not observable. Here again, psychologists insist on various illusions creating discrepancy between modeller's apparent 'reasons' and actor's recognized ones.

Before neuro-economics emerged, a lot of bridge principles between mental states and brain areas were already established by neurologists. Fear was considered as treated by amygdala and angriness by anterior insula. Deduction and abduction were associated to frontal gyrus and Broca area. Neuro-economics added some more bridge principles which concern either basic concepts or 'propensions' (properties of relations). As concerns the first, reward is associated to orbito-frontal cortex, trust to anterior cortex and paracingulate. As concerns the second, intertemporal trade-off is associated to the limbic structure and risk aversion to amygdala. Such bridge principles are not biunivoque and not even univoque since a mental state corresponds to several areas and an area is involved in several mental states. They are of an empirical nature as soon as the mental states are declared prior to the brain investigation. They are ascendant since it is generally

excluded that mental states retroact on brain signals and synchronic since the mental states are declared simultaneously to brain signals.

A consequence of bridge principles summarized in the form of an identity is that the same concept can be measured (eventually on different scales) at different organization levels. The best example concerns the three measures of the utility got by an actor being subjected to consequences of some action. Anyone may be considered *ex post* if it is felt by the actor after implementing his decision or *ex ante* if it is expected by the actor in order to fix his decision. *Revealed utility* is revealed by the modeller who observes the player's past actions and it is naturally defined ex ante. *Experienced utility* (or hedonistic utility) is declared by the actor and is essentially measured ex post. *Neural utility* is assessed by the modeller observing the intensity of firing of the relevant area and it can be ex ante or ex post. Note that neuro-biologists speak of reward rather than (neural) utility since they consider it as a quantitative and objective variable which is not necessarily linked to a decision. For the modeller, the three measures of utility may be different and they receive in fact different interpretations.

6 Bridge Correspondances between Models

Defined on concepts and propensions, the bridge principles can be extended to 'bridge correspondences' acting on relations and models. Knowing a regular relation between microscopic variables and several bridge principles relating a macroscopic variable to the microscopic ones, it is often possible to eliminate the last in order to generate a relation between macroscopic variables only. This is well illustrated in eco-economics where individual relations are 'aggregated' into a global one. From relations between consumption and revenue for each individual and from definition of global consumption and revenue, one gets a relation between the last. But this transformation is only possible when some drastic 'aggregation conditions' are satisfied. More generally, a macroscopic mechanism results from the behaviours of microscopic entities, relations between them and bridge principles. For decision theory, bridge correspondences apply to partial operations (expectation of effects, evaluation of consequences, comparison of options) or to the whole choice process.

In psycho-economics, the equivalences between models at the mental and behavioural levels are trivial. If the declared and revealed mental states are assimilated, the models at each level may be structurally the same. But some constraints may be active at the mental level and influence the behavioural level in a different way. For instance, computational constraints on reasoning have necessarily an impact on the agent's decision process. Such an impact may be introduced in the rational model by hidden costs of

gathering and computing information. However, when taking computation costs into account in the optimizing model, an infinite regression appears without any possible escape from this logical paradox (Mongin & Walliser, 1987). The computational constraints are more naturally expressed by the bounded rationality notion in Simon's sense. He proposed some models at the behavioural level such as the 'satisficing model' where the actor's computation costs are reduced (Simon, 1997). But he did not make explicit how computational constraints entails this choice model rather than any other.

In neuro-economics, some relations between models at the neural and mental levels are proposed. For instance, the prefrontal cortex is composed of three areas (Kouneiher, Charron & Koechlin, 2009) which cooperate in the choice process. The inferior face is associated with an evaluative dimension (subjective preference on consequences). The external lateral face is associated with a cognitive dimension (context of action). The internal lateral face is associated with a motivational dimension (subjective value of each action). The second area is itself devoted to the immediate context of action, to the occurrence of past events and to the sequentiality of actions. In other respects, neuro-biologists also introduced the 'theory of mentalization' which states that the same brain areas (medial prefrontal cortex) are activated when the mental states refer to the actor himself or to a perceived opponent. This theory may justify the 'cognitive hierarchy model' in game theory, in which the actors are distributed according to their maximal level of crossed beliefs (Camerer, Ho & Chong, 2004).

In fact, mechanisms proposed at different levels are based on different kinds of explanation schemes. At the neural level, mechanisms concerning the relations between brain areas are of a causal nature. At the mental level, mechanisms concerning the relations between various mental states are purely logical. At the behavioural level, mechanisms between actions and revealed mental states are teleological, mental states acting as 'reasons' for action. It follows that the empirical bridge principles are problematic as concerns the type of explanation involved. From neural to mental level, they concern the transformation of brain signals into mental states, a completely opaque process. From mental to behavioural level, they concern the transformation of mental states into implemented actions, especially from a virtual to a real action, a badly known process too. The integrist attitude mentioned before and defended by some economists is in part justified by the present fragility of the bridge principles.

7 Methodological Attitudes

Two methodological postulates apply to the structures extracted at each level as well as to the bridge principles. First, the 'universality assumption'

states that the same types of structures apply to all actors in a given situation. In psycho-economics, it expresses that the deliberation processes are the same for all actors confronted to a same situation. Only the mental states differ from one actor to the other and especially the propensions (aversion to risk, time preference, altruistic preference). In neuro-economics, it expresses that the brains are interchangeable, the same mental operations activating the same brain areas, whatever the decision-maker. However, notwithstanding the 'average brain', some perturbations may be observed due to individual variations. These variations, especially pathologies, are carefully examined by psychologists or neurologists contrary to economists.

Second, the 'stability postulate' considers that the structures considered at each level are invariant through time. In psycho-economics, it applies essentially to the properties attributed to the mental states of some actor. More precisely, the individual propensions are assumed to be profoundly anchored in each actor and fixed at least at short term. In fact, if beliefs evolve naturally with new information, preferences were only recently considered as evolving with age, past experience and foreign influence. In neuro-economics, the specialization of brain areas in some precise functions is considered as the result of biological evolution. The geographical map of brain activities is considered as stable in a man's life, even if it needs to develop during childhood. It is considered as stable during the centuries since biological evolution is very slow for a given species.

In all empirical disciplines, scientific activity proceeds by testing prior models against data (projection) or extracting original models from data (induction). In practice, some structural elements of the model are already given while the others are induced from data. In psycho-economics, the frame of the decision process is clearly given by rationality considerations. But the analytical form of the stated relations is estimated with regard to the observations. For instance, in the 'prospect theory' (Kahnemann & Tversky, 1979), the function relating the perceived probability to the objective one and the perceived utility to the obtained payoff are adjusted from the data. In neuro-economics, several decision models may be in competition if they lead to contrasted testable consequences. They are confronted to the brain data which appear very crude, but look nevertheless in accordance or not with each model.

In the same spirit, the modeller checks if a model is compatible with data (confirmation) or proves that it is incompatible (refutation). In fact, with statistical methods, these two attitudes gather in the definition of a model's 'likelihood'. In psycho-economics, some laboratory experiments have tried hard to show that some proposed model is refuted. The best known example is the refutation of the 'expected utility model' by the 'Allais paradox' (Allais, 1953). However, many experiments content with observing that the data are compatible with a given model. In neuro-economics, the main methodology consists in confirming that the data do not

contradict a previously proposed model. However, neuro-economics seems well adapted to a refutation procedure when the brain areas expected to fire are not firing. It is possible to show that some suggested variables play no role, that some postulated relations do not exist or even that some general principles are false.

8 Applications

In any case, psycho-economists as well as neuro-economists adopted an empirical view of the choice process. They reacted to the primitive axiomatic view which looks completely tautological since it reveals the mental states without observing them. In a first step, experimental laboratories were created in many research centres around the world. In a second step, brain imaging machines were introduced in a restricted number of laboratories. Becoming more and more professional with regard to neurosciences, experiences are often shrewd and original, but nevertheless affected by several drawbacks. A general failure concerns the 'problem of parallelism' which wonders if the results in the laboratory can be extended to real life. Another general problem concerns the numerous environmental factors which cannot be mastered. A problem specific to psycho-economics concerns the possible influence of the modeller on the actor. A problem specific to neuro-economics concerns the uncomfortable conditions of experiment for an actor placed horizontally in a scanner.

A first application of experimental results concerns the forecast of an actor's future choice in some context (Camerer, 2007). Since models at each level are very sensitive to the details of their structure, such a prediction entails large margins of error. At the neural level, proposed mechanisms are too coarse to allow forecasts with an acceptable precision. At the mental level, mental states are too numerous, complex and volatile to allow robust expectations. At the behavioural level, revelation is too multi-valued and imprecise to predict future choices adequately. However, considering all levels together with their bridge principles may help to forecast an action since the explaining factors reinforce each other. Applying the bridge principles does not need biunivocity which is very rare, but only univocity. But in practice, even univocity is hard to obtain without succumbing to the 'affirmation of consequent' fallacy. In neuro-economics, it is generally impossible to assume that some mental state is active just by observing the firing of some brain areas.

A second application of empirical works concerns the prescription of an actor's future decision in a given situation. In order to guide some actor in his decision, two different prescriptive attitudes have to be distinguished. On the one hand, the adviser suggests directly to the decision-maker some

action which satisfies his presumed interests. He just reveals the main mental states of the actor and simulates his deliberation process in the best way for him. This is the case for 'neuro-finance' which aims for the expert at providing an investor with the best mental tools for winning at the Stock Exchange. On the other hand, the adviser indicates to the decision-maker how to influence his human targets for his own benefit. The problem consists now to direct the mental preferences of the targets without the last being aware of this influence. This is the case for 'neuro-marketing' which pretends to help the firm better selling its products by manipulating the consumers.

Besides, at the behavioural level, normative eco-economics defined collective evaluation criteria which combine in different ways individual utilities. Since utility assessments are now multiple, the modeller has to choose between the revealed, hedonistic or neural version. The first index was generally preferred since it is not too much manipulable contrary to the second. The third index looks not manipulable at all, but stays too coarse to be used in an operational way. More generally, all applications are grounded on very fragile models and may be refuted very rapidly in the future. A sufficient delay is necessary to transform explanations given by scientists into prescriptions given by experts. Keynes pessimistically asserted in his time that 'any politician is a victim of a dead economist'. One can add today that 'any decision-maker is a potential victim of a well alive psycho- or neuro-economist'.

9 Conclusions

Psycho-economics and neuro-economics were rapidly presented by their promoters as providing a scientific revolution in economics. Many results were considered by their authors as important discoveries able to completely renew the discipline. However, fever has now fallen and no systematic and unbiased assessment of results is available, which distinguishes accepted, controversial and unexplored facts. Some general evaluation can nevertheless be done as concerns the introduction of new variables, new functional forms for relations, new principles or even new types of models. Classical decision theory defined at the behavioural level suggests a useful theoretical framework even if it appears as very demanding. It was confirmed on some points, transformed on some other, augmented in many ways but stays without an uncontroversial competitor.

Psycho-economics induces the modeller to seriously take mental states into account thanks to introspection. It encouraged considering emotions as new factors acting either before, in parallel or after the decision process. It validated some deviations from the maximizing model: deformation of probabilities, hyperbolic preferences, reference situation and limited

cognitive levels. It emphasized the notion of bounded rationality which gave rise to a variety of models such as the satisficing model, the quantal model, the cognitive hierarchy model. It insisted on the context- and history-dependence of all models, especially on the framing effect. It introduced a variety of learning processes where actors compensate a lack of sophisticated reasoning by their experience acquired through time. But it stays mute about the dynamic aspects of the choice process or about the cultural aspects of decision.

Neuro-economics challenges the modeller to give a more objective foundation to the mental states. It gives more importance to beliefs than to preferences at the contrary of classical economics. It validates some classical opposite concepts: beliefs vs. preferences, risk vs. uncertainty, gains vs. losses. It makes clear that the brain acts differently against risk, against uncertainty or against human actors. It insists on infra-conscious choice mechanisms, but also on the influence that consciousness may exert on the choice process. It stresses the importance of the degree of confidence that each actor forms on his judgments in a meta-cognitive way. It proposes a dual model of choice depending on context (Kahneman & Frederick, 2002) and opposing a controlled (cognitive, rational) one and an automatic (affective, mechanistic) one. But the bridge principles linking brain areas to mental states stay imperfect and incomplete and the relations between brain areas stay unknown.

This movement finally associates three professions -economists, psychologists, neurologists- with their own cultures. Initially, economists provided a theoretical framework and were happy to see some psychologists testing them. Through the 'experimental economics' movement, they rapidly followed them by making their own experiences. Psychologists brought some theoretical insights, but essentially noticed that the classical model suffers from many defaults. They confirmed the possibility of making economics more empirical, hence prepared the work for neuro-economics. Economists again provided neuro-economists with theoretical models, but at a lower degree of specificity. Neuro-economists introduced new observation techniques, keeping control of their heavy and costly experiments. They develop nowadays their own theoretical models and even practice some entrism on other specialities. Beyond interdisciplinary concerns, the neuroscience component is nowadays favoured since it appears as the most 'scientific' and allows the authors to publish in 'Science' or 'Nature'.

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