Trading by Quantum Rules – Quantum Anthropic Principle

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Abstract

This is a short review of the background and recent development in quantum game theory and its possible application in economics and finance. The intersection of science and society is discussed and Quantum Anthropic Principle is put forward. The review is addressed to non-specialists.

One hundred years ago, a single concept changed our world view forever (Zellinger, 2000). Contemporary technology is based on implementation of quantum phenomena as a result of this seminal idea. Now only social sciences persist in classical paradigm what might be considered as an obstacle to unification of science in the quantum domain. Quantum theory is up to now the only scientific theory that requires of observer that he takes into consideration the usually neglected influence of the method of observation on the result of observation. Full and absolutely objective information about the investigated phenomenon is impossible and this is a fundamental principle of Nature and not deficiency in our technology. Critics of the possibility of application of quantum methods in the domain of political and social sciences often ignore this fact. A new way of perceiving the reality implies fascinating conclusions (Deutsch, 1997) that dim the non-scientific visions of SF literature and Hollywood output. This approach seems to be consistent with scientific experiments. If fundamental phenomena (e.g. microworld) do not allow for classical description why should economics phenomena do? Maybe the modest quantitative achievements of social sciences if compared with precise results of experiments performed by physicists result only from the persistence in the classical paradigm? Will we manage to extend the domain of the quantum paradigm to include social sciences? The answer should be known within a few years.

At the beginning of the XXI century first papers devoted to quantum description of markets (Piotrowski and Sładkowski, 2001; 2002a; 2002b; 2002d) were published. But before we characterize this approach let us recall scientific achievements that made it possible. We have got used to simulations (modelling) of the surroundings and various phenomena on computers. Contemporary computers act according the Turing ideas but some 20 years ago Richard P. Feynman (Feynman, 1982; 1986) argued that fundamental and well understood properties of Nature prevent almost every physical process from being successfully simulated on a Turing machine (i. e. computer). Such well known phenomena as stability of matter, chemical reactions, conductivity, evolution of stars and so on can only be understood on the quantum level. Modern technologies are developed only due to investigation into quantum nature of matter. The powerful computers that are at our disposal, although classical in the sense to be explained below, are constructed due to the achievements of quantum condensed matter physics. So what is the problem? There is one: computational complexity. Roughly speaking algorithms can become so complicated that computation is in fact impossible (Penrose, 1994). (We do not want to go into the details of the beautiful mathematical theory of computation but there are also problems that cannot be solved at all!). Feynman drew the following conclusion. Turing's ideas should be reformulated so that they would incorporate the quantum character of Nature (according to the modern physics all phenomena described in classical way are only asymptotic or averaged results of quantum processes). For example we have got an excellent theory of electro-magnetic interactions (quantum electrodynamics) but to describe, say, the scattering of two electrons at the precision required by contemporary experiments several teams of experienced physicists have to work for several years. This should be compared with the actual behaviour of the electrons in question: they just scatter in the twinkling of an eye without any computation (in the common meaning of the word). There should be a quantum computer, whatever it means, that performs better! In 1994 Peter Shor invented a fast quantum algorithm for prime factoring of natural numbers (Shor, 1994). This is an example of a problem that is extremely difficult to solve on a Turing machine. Due to its computational complexity prime factoring is used in the nowadays most popular cryptographic system (RSA). But, as Shor showed us, prime factoring is quite an easy task on a quantum computer, provided we have got one. This means that RSA codes can be broken! There are already first successful probes of simple quantum computations (Vandersypen et al, 2001). Of course, these computation can be faster and cheaper done by hand but nevertheless these experiment are promising. The thorough investigation of quantum entangled states speeded up the development of quantum cryptography that is immune even to attacks by quantum algorithms. All these results induced scientist to consider quantum strategies in games what gave birth to quantum game theory that generalizes the classical von Neumann's ideas (Klarreich, E. 2001a) (paradoxically this outstanding mathematician was also the author mathematical formalism of quantum theory) . A lot of newspapers announced this achievement in 1999.

Iqbal and Toor have applied the method of quantization of games proposed by Marinatto and Weber (Marinatto and Weber, 2000) in biology. Their results are very interesting (Iqbal and Toor (2001a; 2001b; 2002a). Recently they have used the same formalism to analyse the Stackelberg duopoly (or leader-follower model) (Iqbal and Toor, 2002b). In the classical setting the follower becomes worse-off compared to the leader who becomes better-off. Iqbal and Toor have shown that in the quantum setting the follower is not hurt even if he or she knows the action of the leader. The backward induction outcome is the same as the Nash equilibrium in the classical Cournot game that is when decision are made simultaneously and there is no information hurting players.

The above approach was influenced by the development of quantum cryptography so the contest takes place on a "quantum board" - the set of possible states of the game. This might suggest that non-classical aspects of various games could reveal themselves only under very sophisticated conditions when ultra-modern quantum technologies would make possible the existence of futuristic markets or stock exchanges. On such would-be markets strategies, being unitary operations, will be extremely sensitive to perturbation destroying quantum coherence. This will assure absolute privacy and unavoidable detection of any manipulation (no deleting theorem). But this promising future, despite its subtle technological constraint, must not necessarily be the only way of benefiting from the rich and sometimes surprising opportunities offered by quantum theory. We have managed to formulate a new approach to quantum game theory that is suitable for description of market transactions in term of supply and demand curves (Piotrowski and Sładkowski, 2001; 2002a; 2002b; 2002d). In this approach quantum strategies are vectors in some Hilbert space and can be interpreted as superpositions of trading decisions. For an economist (or trader) they form the potential "quantum board". Due to the possible economics context the quantum strategies reveal a lot of interesting properties. Supply strategies of market objects are Fourier transforms of their respective demand states. Strategies and not the apparatus nor the installation for actual playing are at the very core of the theory. If necessary the actual subject of investigation may consist of single traders, teams of traders or even the whole market. Of course, sophisticated equipment built according to quantum rules may be necessary for generating or clearing quantum market but we must not exclude the possibility that human consciousness (brain) performs that task equally well. Even more, a sort of quantum playing board may be the natural theater of "conflict games" played by our consciousness (Penrose, 1994). We envisage that in future, instead of penetration of the innermost recesses of the brain, very interesting problems can be approached by investigation of the possible quantum features of human behaviour. It is possible that elementary "components" of consciousness are formed by wave function spread over large domains and having no concrete localization (as those of electrons forming electrical current). It is worth to note here that recent investigations reveal sort of randomness in brain's responses that may be of quantum origin (Klarreich, 2002b). If human strategies are collective properties of molecules forming neural system then quantum automata might be the only tools to describe real social games. This should be compared with phonons (collective excitations in solids) that escapes our perception if the cristalline network is decomposed into its basic ingredients. We should stress here that quantization does not simple mean introducing elements of randomness into the model. Quantum theory is different from statistical description on both qualitative and quantitative level (Deutsch, 1997; Feynman, 1982; Penrose, 1994).

In the newly proposed approach spontaneous or institutionalized market transactions are described in terms of projective operation acting on Hilbert spaces of strategies of the traders. Quantum entanglement is necessary to strike the balance of trade. The text-book examples of departures from the demand-supply law are related to the negative probabilities that often emerge in quantum theories and form very interesting illustrations of them (Piotrowski and Sładkowski, 2002a; 2002b; Sładkowski, 2003). This theory predicts the property of undividity of attention of traders (no cloning theorem). The sudden and violent changes of prices can be explained by the quantum Zeno phenomenon. The theory unifies also the English auction with the Vickrey's one attenuating the motivation properties of the latter. There are apparent analogies with quantum thermodynamics that allow to interpret market equilibrium as a state with vanishing financial risk flow. Sometimes euphoria, panic or herd instinct cause violent changes of market prices. Such phenomena can be described by non-commutative quantum mechanics. There is a simple tactics that maximize the trader's profit on an effective market (Piotrowski and Sładkowski, (2002e). It can be expressed as *accept profits equal or greater then the one you have formerly achieved on average.*

Even if at early civilization stages markets are governed by classical laws (this can be questioned (Penrose, 1994)) the incomparable efficacy of quantum algorithms in multiplying profits should result in such market evolution so that quantum behaviour will be prevailing over the classical one. This *quantum anthropic principle* (Piotrowski and Sładkowski, 2001) could have been observed at work in the former century: quantum description was more effective and economical from both technological and economic points of view and the quantum paradigm replaced the classical one. Nowadays an essential part of transactions made on NYSE or NASDAQ are in fact made by computers. We envisage that these computers will be replaced by quantum ones. Quantum market games broaden our horizons and offer new opportunities for the economy. On the other hand, "*It might be that while observing the due ceremonial of everyday market transaction we are in fact observing capital flows resulting from quantum* *games eluding classical description. If human decisions can be traced to microscopic quantum events one would expect that nature would have taken advantage of quantum computation in evolving complex brains. In that sense one could indeed say that quantum computers are playing their market games according to quantum rules*" (Mayer, 2001). David Deutsch has proposed an interesting unification of theories of information, evolution and quanta (Deutsch, 1997). Lambertini put forward arguments for obeserving Schroedinger cat like objects on real markets (Lambertini, 2000). But why quantum social sciences should emerge just now (Mendes, 2002)? They could have not emerged earlier because a tournament quantum computer versus classical one is not possible without technological development necessary for a construction of quantum computers. Quantum-like approach to market description might turn out to be an important theoretical tool for investigation of computability problems in economics or game theory even if never implemented in real market (Velupillai, 2000; Waite, 2002).

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