

# Contents

<b>1</b>	<b>Quantum-like Paradigm</b>	<b>1</b>
1.1	Applications of Mathematical Apparatus of QM Outside of Physics	1
1.2	Irreducible Quantum Randomness, Copenhagen Interpretation	2
1.3	Quantum Reductionism in Biology and Cognitive Science	3
1.4	Statistical (or Ensemble) Interpretation of QM	4
1.5	No-Go Theorems	5
1.6	Einstein's and Bohr's Views on Realism	6
1.7	Quantum and Quantum-like Models	7
1.8	Quantum-like Representation Algorithm – QLRA	7
1.9	Non-Kolmogorov Probability	8
1.10	Contextual Probabilistic Model – Växjö Model	9
1.11	Experimental Verification	10
1.12	Violation of Savage's Sure Thing Principle	11
1.13	Quantum-like Description of the Financial Market	11
1.14	Quantum and Quantum-like Games	13
1.15	Terminology: Context, Contextual Probability, Contextuality	14
1.16	Formula of Total Probability	15
1.17	Formula of Total Probability with Interference Term	15
1.18	Quantum-like Representation of Contexts	16
<b>2</b>	<b>Classical (Kolmogorovian) and Quantum (Born) Probability</b>	<b>19</b>
2.1	Kolmogorovian Probabilistic Model	19
2.1.1	Probability Space	19
2.1.2	Conditional Probability	22
2.1.3	Formula of Total Probability	24
2.2	Probabilistic Incompatibility: Bell–Boole Inequalities	25
2.2.1	Views of Boole, Kolmogorov, and Vorob'ev	26
2.2.2	Bell's and Wigner's Inequalities	28
2.2.3	Bell-type Inequalities for Conditional Probabilities	28
2.3	Quantum Probabilistic Model	29
2.3.1	Postulates	30

2.3.2	Quantization .....	33
2.3.3	Interpretations of Wave Function .....	34
2.4	Quantum Conditional Probability .....	35
2.5	Interference of Probabilities in Quantum Mechanics .....	36
2.6	Contextual Point of View of Interference .....	38
2.7	Bell's Inequality in Quantum Physics .....	38
2.8	Växjö Interpretation of Quantum Mechanics .....	40
<b>3</b>	<b>Contextual Probabilistic Model – Växjö Model .....</b>	<b>41</b>
3.1	Contextual Description of Observations .....	41
3.1.1	Contextual Probability Space and Model .....	41
3.1.2	Selection Contexts; Analogy with Projection Postulate ..	43
3.1.3	Transition Probabilities, Reference Observables .....	43
3.1.4	Covariance .....	44
3.1.5	Interpretations of Contextual Probabilities .....	45
3.2	Formula of Total Probability with Interference Term .....	46
<b>4</b>	<b>Quantum-like Representation Algorithm – QLRA .....</b>	<b>49</b>
4.1	Inversion of Born's Rule .....	50
4.2	QLRA: Complex Representation .....	51
4.3	Visualization on Bloch's Sphere .....	55
4.4	The Case of Non-Doubly Stochastic Matrices .....	57
4.5	QLRA: Hyperbolic Representation .....	58
4.5.1	Hyperbolic Born's Rule .....	58
4.5.2	Hyperbolic Hilbert Space Representation .....	60
4.6	Bloch's Hyperboloid .....	61
<b>5</b>	<b>The Quantum-like Brain .....</b>	<b>65</b>
5.1	Quantum and Quantum-like Cognitive Models .....	65
5.2	Interference of Minds .....	68
5.2.1	Cognitive and Social Contexts; Observables .....	68
5.2.2	Quantum-like Structure of Experimental Mental Data ...	69
5.2.3	Contextual Redundancy .....	70
5.2.4	Mental Wave Function .....	72
5.3	Quantum-like Projection of Mental Reality .....	72
5.3.1	Social Opinion Poll .....	72
5.3.2	Quantum-like Functioning of Neuronal Structures .....	73
5.4	Quantum-like Consciousness .....	75
5.5	The Brain as a Quantum-like Computer .....	76
5.6	Evolution of Mental Wave Function .....	76
5.6.1	Structure of a Set of Mental States .....	77
5.6.2	Combining Neuronal Realism with Quantum-like Formalism .....	78

<b>6</b>	<b>Experimental Tests of Quantum-like Behavior of the Mind</b>	<b>79</b>
6.1	Theoretical Foundations of Experiment	79
6.2	Gestalt Perception Theory	80
6.3	Gestalt-like Experiment for Quantum-like Behavior of the Mind	81
6.4	Analysis of Cognitive Entities	84
6.5	Description of Experiment on Image Recognition	86
6.5.1	Preparation	87
6.5.2	First Experiment: Slight Deformations Versus Short Exposure Time	87
6.5.3	Second Experiment: Essential Deformations Versus Long Exposure Time	88
6.6	Interference Effect at the Financial Market?	90
6.6.1	Supplementary ("complementary") Stocks	90
6.6.2	Experiment Design	91
<b>7</b>	<b>Quantum-like Decision Making and Disjunction Effect</b>	<b>93</b>
7.1	Sure Thing Principle, Disjunction Effect	93
7.2	Quantum-like Decision Making: General Discussion and Postulates	96
7.2.1	Superposition of Choices	98
7.2.2	Parallelism of Creation and Processing of Mental Wave function	99
7.2.3	Quantum-like Rationality	99
7.2.4	Quantum-like Ethics	100
7.3	Rational Behavior, Prisoner's Dilemma	100
7.4	Contextual Analysis of Experiments with Disjunction Effect	101
7.4.1	Prisoner's Dilemma	101
7.4.2	Gambling Experiment	104
7.4.3	Exam's Result and Hawaii Experiment	105
7.5	Reason-Based Choice and Its Quantum-like Interpretation	105
7.6	Coefficients of Interference and Quantum-like Representation	106
7.7	Non-double Stochasticity of Matrices of Transition Probabilities in Cognitive Psychology	107
7.8	Decision Making	108
7.9	Bayesian Updating of Mental State Distribution	110
7.10	Mixed State Representation	112
7.11	Comparison with Standard Quantum Decision-Making Theory	112
7.12	Bayes Risk	113
7.13	Conclusion	114
<b>8</b>	<b>Macroscopic Games and Quantum Logic</b>	<b>115</b>
8.1	Spin-One-Half Example of a Quantum-like Game	117
8.2	Spin-One Quantum-like Game	122
8.3	Interference of Probability in Quantum-like Games	127

8.4	Wave Functions in Macroscopic Quantum-like Games .....	129
8.5	Spin-One-Half Game with Three Observables .....	132
8.6	Heisenberg's Uncertainty Relations .....	134
8.7	Cooperative Quantum-like Games, Entanglement .....	135
<b>9</b>	<b>Contextual Approach to Quantum-like Macroscopic Games .....</b>	<b>137</b>
9.1	Quantum Probability and Game Theory .....	137
9.2	Wine Testing Game .....	138
9.3	Extensive Form Game with Imperfect Information .....	141
9.3.1	Quantum-like Representation of the Wine Testing Game .....	142
9.3.2	Superposition of Preferences .....	143
9.3.3	Interpretation of Gambling Wave Function .....	143
9.3.4	The Role of Bayes Formula .....	144
9.3.5	Action at a Distance? .....	145
9.4	Wine Game with Three Players .....	145
9.5	Simulation of the Wine Game .....	146
9.6	Bell's Inequality for Averages of Payoffs .....	147
<b>10</b>	<b>Psycho-financial Model .....</b>	<b>151</b>
10.1	Deterministic and Stochastic Models of Financial Markets .....	151
10.1.1	Efficient Market Hypothesis .....	151
10.1.2	Deterministic Models for Dynamics of Prices .....	152
10.1.3	Behavioral Finance and Economics .....	153
10.1.4	Quantum-like Model for Behavioral Finance .....	154
10.2	Classical Econophysical Model of the Financial Market .....	155
10.2.1	Financial Phase Space .....	155
10.2.2	Classical Dynamics .....	157
10.2.3	Critique of Classical Econophysics .....	159
10.3	Quantum-like Econophysical Model of the Financial Market ....	160
10.3.1	Financial Pilot Waves .....	160
10.3.2	Dynamics of Prices Guided by Financial Pilot Wave ....	161
10.4	Application of Quantum Formalism to the Financial Market ....	165
10.5	Standard Deviation of Price .....	166
10.6	Comparison with Conventional Models of the Financial Market ..	167
10.6.1	Stochastic Model .....	167
10.6.2	Deterministic Dynamical Model .....	169
10.6.3	Stochastic Model and Expectations of Agents of the Financial Market .....	170
<b>11</b>	<b>The Problem of Smoothness of Bohmian Trajectories .....</b>	<b>171</b>
11.1	Existence Theorems for Nonsmooth Financial Forces .....	171
11.1.1	The Problem of Smoothness of Price Trajectories .....	171
11.1.2	Picard's Theorem and its Generalization .....	173
11.2	The Problem of Quadratic Variation .....	176

11.3	Singular Potentials and Forces .....	177
11.3.1	Example .....	177
11.3.2	Singular Quantum Potentials .....	177
11.4	Classical and Quantum Financial Randomness .....	178
11.4.1	Randomness of Initial Conditions .....	179
11.4.2	Random Financial Mass .....	179
11.5	Bohm–Vigier Stochastic Mechanics .....	180
11.6	Bohmian Model and Models with Stochastic Volatility .....	182
11.7	Classical and Quantum Contributions to Financial Randomness ..	183
<b>12</b>	<b>Appendix .....</b>	<b>185</b>
12.1	Independence .....	185
12.1.1	Kolmogorovian Model .....	185
12.1.2	Quantum Model .....	186
12.1.3	Växjö Model .....	187
12.2	Proof of Wigner’s Inequality .....	188
12.3	Projection Postulate .....	190
12.4	Contextual View of Kolmogorov and Quantum Models .....	190
12.4.1	Contextual Models Induced by the Classical (Kolmogorov) Model .....	190
12.4.2	Contextual Models Induced by the Quantum (Dirac–von neumann) Model .....	191
12.5	Generalization of Quantum Formalism .....	191
12.6	Bohmian Mechanics .....	194
	<b>References .....</b>	<b>199</b>
	<b>Index .....</b>	<b>213</b>