

QUANTUM CONCEPTS IN THE SOCIAL, ECOLOGICAL AND BIOLOGICAL SCIENCES

Quantum mechanics is traditionally associated with microscopic systems; however, quantum concepts have also been successfully applied to a diverse range of macroscopic systems both within and outside of physics. This book describes how complex systems from a variety of fields can be modeled using quantum mechanical tools, from biology and ecology to sociology and decision-making. The mathematical basis of these models is covered in detail, furnishing a self-contained and consistent approach. This book provides unique insight into the dynamics of these macroscopic systems and opens new interdisciplinary research frontiers. It will be an essential resource for students and researchers in applied mathematics or theoretical physics who are interested in applying quantum mechanics to dynamical systems in the social, biological or ecological sciences.

FABIO BAGARELLO is Professor of Mathematical Physics and Mathematical Methods at the University of Palermo. His research interests include the application of quantum mechanics to macroscopic systems and the application of functional analysis and operator theory to quantum mechanics. He is the author of numerous scientific articles on these topics in addition to four books and several edited volumes.

Cambridge University Press

978-1-108-49212-6 — Quantum Concepts in the Social, Ecological and Biological Sciences

Fabio Bagarello

Frontmatter

[More Information](#)

QUANTUM CONCEPTS IN THE
SOCIAL, ECOLOGICAL AND
BIOLOGICAL SCIENCES

FABIO BAGARELLO

University of Palermo



CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
314-321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi - 110025, India
79 Anson Road, #06-04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.
It furthers the University's mission by disseminating knowledge in the pursuit of
education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108492126
DOI: 10.1017/9781108684781

© Fabio Bagarello 2019

This publication is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without the written
permission of Cambridge University Press.

First published 2019

Printed in the United Kingdom by TJ International Ltd, Padstow Cornwall
A catalog record for this publication is available from the British Library.

ISBN 978-1-108-49212-6 Hardback

Cambridge University Press has no responsibility for the persistence or accuracy
of URLs for external or third-party internet websites referred to in this publication
and does not guarantee that any content on such websites is, or will remain,
accurate or appropriate.

As always, I dedicate this book to my beloved parents, Giovanna and Benedetto, and to Federico, Giovanna and Grazyna, with pure and diverging (to $+\infty!$) love. I wish for them to enjoy their lives much more than I do (and please consider that I am already quite satisfied).

Cambridge University Press

978-1-108-49212-6 — Quantum Concepts in the Social, Ecological and Biological Sciences

Fabio Bagarello

Frontmatter

[More Information](#)

Contents

	<i>Preface</i>	page xi
	<i>Acknowledgments</i>	xiii
1	Why a Quantum Tool in Classical Contexts? (Part II)	1
1.1	Organization of the Book	3
	Part I The General Framework	5
2	Some Preliminaries	7
2.1	The Bosonic Number Operator	7
2.2	The Fermionic Number Operator	11
2.3	Other Possibilities	12
2.4	Dynamics for a Quantum System	21
2.5	Heisenberg Uncertainty Principle	28
2.6	A few Words on States	31
2.7	More on Dynamics	33
2.8	The (H, ρ) -Induced Dynamics	43
2.9	A Two-Mode System	51
	Part II Applications	57
3	Politics	59
3.1	Introduction	59
3.2	A First Model	60
3.3	Extending the Model, Part 1: More Interactions	87
3.4	Extending the Model, Part 2: Adding a <i>Rule</i> ρ	97
3.5	Nonlinearities	105
3.6	Conclusions	112

viii	<i>Contents</i>	
4	Desertification	113
	4.1 Introduction	113
	4.2 The Model	114
	4.3 Numerical Results	120
	4.4 Conclusions	139
5	Escape Strategies	141
	5.1 Introduction	141
	5.2 The Model	142
	5.3 Numerical Simulations	147
	5.4 Conclusions	167
6	Closed Ecosystems	168
	6.1 A Linear Model with a Single Garbage	169
	6.2 A Linear Model with Two Garbages	172
	6.3 A Nonlinear Model with Two Garbages	179
	6.4 A Phenomenological Damping	185
	6.5 Conclusions	193
7	More on Biological Systems	194
	7.1 Introduction	194
	7.2 Tumor Cell Proliferation	195
	7.3 Numerical Results	199
	7.4 Conclusions	205
8	Quantum Game of Life and Its (H, ρ) -Induced Dynamics	206
	8.1 Introduction	206
	8.2 The Quantum Game of Life	209
	8.3 Some Results	213
	8.4 Conclusions	216
9	Prehistoric Data Mining	217
	9.1 Introduction	217
	9.2 Introducing the Model	219
	9.3 Results	229
	9.4 Conclusions	233
10	A Simple Model of Information in Stock Markets	234
	10.1 Introduction	234
	10.2 Before the Trading Begins	235
	10.3 After the Trading Has Begun	241
	10.4 Conclusions	248

<i>Contents</i>		ix
11	Decision-Making Driven by the Environment	250
11.1	Introduction	250
11.2	The Environment and Its Hamiltonian	251
11.3	Asymptotic Values: Absence of Interferences	259
11.4	Finite Time Behavior: The Role of Interference	262
11.5	Conclusions	266
12	Compatible and Incompatible Questions	267
12.1	Introduction	267
12.2	The Mathematical Framework	268
12.3	An Application to Decision-Making and Order Effect	283
12.4	Conclusions	285
13	This Is Not the End...	287
13.1	What Next?	288
	<i>References</i>	290
	<i>Index</i>	297

Cambridge University Press

978-1-108-49212-6 — Quantum Concepts in the Social, Ecological and Biological Sciences

Fabio Bagarello

Frontmatter

[More Information](#)

Preface

I like to do research, and I like to move from one topic to another. Otherwise, I easily get bored! But from time to time, I feel the necessity to stop and think of what I have produced up to that moment, alone or with a group of colleagues, who quite often are also friends. And this is exactly the right moment to stop and summarize what has been done during the past few years after adopting my operatorial approach to mathematical modeling – which is exactly what this book is about. Writing a book also gives you a nice opportunity: one needs to reflect again and again on things which, when you write an article, may appear simple and clear. But sometimes you realize that what appeared to be simple years ago is not simple at all, and it possibly deserves a deeper analysis and a better understanding. And this is something I like: my old (or recent) results live again, give new suggestions and drive me toward unexpected directions. I am forced to read material on topics which are, in principle, far away from my usual *know-how*: ecology, economy, biology and anthropology are just a few such topics, but aren't the only ones. And this is a nice way to learn many amazing things.... Hence, I consider this book as the conclusion of a long period of study and the beginning of a new one. At least, this is what I hope. And I also do hope that you will enjoy reading this book, and that it will spark your curiosity, encourage you to start forming ideas of your own and then see if those ideas can be transformed into formulas according to the framework described in the chapters to follow. In fact, this is also what a book is for: to attract people! So, please, come and join me: everyone is welcome!

Cambridge University Press

978-1-108-49212-6 — Quantum Concepts in the Social, Ecological and Biological Sciences

Fabio Bagarello

Frontmatter

[More Information](#)

Acknowledgments

It is really a pleasure to thank all the people who significantly contributed to my research in this field along the years, starting with the old ones, Franco Oliveri and Francesco Gargano, going to the recent friends, Emmanuel Haven and Rosa Di Salvo, and ending with the brand-new ones, Andrei Khrennikov, Irina Basieva, Emmanuel Pothos, Lucia Tamburino and Giangiacomo Bravo. Their help has been precious in ∞^∞ situations! And they will soon discover I still need them!

Some of the figures you will see appeared (as they are, or in some slightly modified form) in a few articles of mine. The editors kindly gave me the permission to use them, and for this reason I thank all of them. In particular, I wish to thank SIAM for some figures in Chapters 3 and 4, Elsevier for others in Chapters 3, 5, 6, 8 and 12 and Springer for more figures in Chapter 3. I also wish to thank Entropy, Plos One and Philosophical Transaction A for allowing me to use the figures in Chapters 7, 9 and 11.

Cambridge University Press

978-1-108-49212-6 — Quantum Concepts in the Social, Ecological and Biological Sciences

Fabio Bagarello

Frontmatter

[More Information](#)
