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MATCHMAKERS
AND MARKETS

THE REVOLUTIONARY
ROLE OF INFORMATION
IN THE ECONOMY

YI-CHENG ZHANG

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Foreword by Berno Buechel

This book starts by criticizing the kind of economics that I regularly teach to undergraduates, and in some cases to graduate students. Instead of simply offending traditional economics, it provides a healthy criticism that opens the eyes to blind spots and, more importantly, provides an alternative view on how markets work. This view is novel and exciting, and convincingly explains several phenomena that emerge in the digital economy. I highly enjoyed reading this book. I believe that it will have a deep impact on me, as well as on many of you.

When I first met Yi-Cheng Zhang, I aimed to bring together his knowledge as a renowned physicist and my knowledge as an economics professor, to collaborate on the emerging field of *network science*. Little did I know that he would soon be teaching me economics.

Digitalization is transforming the economy in innumerable ways. This leads to phenomena that traditional models fall short of explaining. This book manages to elegantly explain several of these. Consider the rise of several Internet giants whose businesses can be described as matchmaking or operating two-sided platforms. Only recently have economists started to analyse such two-sided platforms. Their focus is often on strategic price setting, whereas Prof Zhang emphasizes the fundamental importance of information. And while economic models are often static and somehow restrictive, he widens the view for *an ecosystem of information that is dynamic and open*. Hence the approaches are complementary, and there is indeed much to learn from each other.

Understanding the value of rigorous theory and having open eyes for the complexity of life are not two opposing forces. On the contrary, it is their combination that helps us deepen the reflection on a topic, and it clearly does so for the theoretical physicist who wrote this book. It can also work for economists and everyone else. As an economist specializing in network science, I have seen a similar turning point. For a long time, economists had analysed decisions of consumers and firms without taking into account how they are embedded in a network of connections. When social networks became a flourishing field in economics during the last two decades, there were already rich strands of literature in various disciplines—from sociology to physics—that could be (re)discovered. Economics can tremendously benefit from

such a fruitful exchange with other disciplines, and it offers its own insights in return.

This book contains remarkably innovative views, and is filled with wisdom. The content is based on solid scientific grounds, while the presentation makes it easy to access and fun to read. I also use it for teaching. For instance, in my graduate course ‘Digital Economy’ I want my students to understand the different roles of matchmakers and the importance of recommender systems, for which this book is also enlightening. To undergraduate students in the ‘Microeconomics’ course it illustrates, among other concepts, how restrictive it is to assume that a consumer knows all available products. I highly recommend this book to students of management and economics around the world, as well as to the practitioners in Silicon Valley and other regions. For everyone interested in the digital economy, I consider it a must-read.

Prof Zhang is a renowned scholar in physics and beyond. The frequency that his work is cited and his role for the company Alibaba are just simple indications of the highest respect that he receives in both the academic world and the business world, and I am proud to call him my colleague and friend. Being neither billionaire nor Nobel Prize laureate (not even close!), I feel honored to contribute this Foreword. I hope that you will all share my enthusiasm for this book and I wish you a wonderful journey of reflection.

Berno Buechel is a professor of economics at the University of Fribourg (Switzerland) and co-founder of the Swiss Center for Data + Network Sciences. His research focuses on the working of markets on strategic behavior and on the role of social networks.

Foreword by Jean-Philippe Bouchaud

In the wake of the 2008 Great Recession, critics of mainstream economics have become more and more vocal. Whereas Robert Lucas argued that “the crisis was not predicted because economics theory predicts that crises cannot be predicted,” Willem Buiter, in one of the most insightful and damning pieces I have read, wrote that “most mainstream macroeconomic theoretical innovations since the 1970s have turned out to be self-referential, inward-looking distractions at best. Research tended to be motivated by the internal logic, intellectual sunk capital, and aesthetic puzzles of established research programmes rather than by a powerful desire to understand how the economy works—let alone how the economy works during times of stress and financial instability.”¹

The search for a new paradigm in fact predates the crisis, with many luminaries (H. Minsky, R. Shiller, R. Thaler, and D. Kahneman, among others) insisting on the importance of behavioral biases and of feedback loops that jeopardize the pillars on which economic theory has been resting in the past fifty years. Although these ideas have progressively made their way into the mainstream, their status is still ambiguous: you need a model to beat a model. Unfortunately, there is at this stage no consistent framework that can compete with the powerful methods of classical economics, which deals with a world where agents face a series of well-posed optimization problems for which all constraints are known and all states of the world are identified. Markets are perfect and reveal all known unknowns and all probabilities. The only problem is to compute the optimal solution. All other contingencies are taken care of by the magic of the invisible hand. As F. Hahn has said: “We need not worry about exhaustible resources because they will always have prices which ensure their proper use.”²

In the present inspiring and deeply original essay, driven by a powerful desire to understand how the economy works, Prof Zhang explains how the world we live in fundamentally differs from the one modeled by economists. This is particularly true of our post-Internet world, where information plays an ever-growing role. The *quantity* of stuff that we produce—an obsession born during war times—becomes secondary to the *quality* of the stuff we consume, of our leisure time and of our

quality of life. In fact, quantity becomes irrelevant when our very survival and that of our environment is at stake. But these aspects are nowhere encoded in the “utility functions” that firms and households are supposed to optimize. No wonder little progress can be made based on traditional cost–benefit analyses.

Prof Zhang argues that it is just not enough to recognize that humans are prone to behavioral biases, and that imperfections and frictions abound in a world otherwise well captured by the framework of classical economics. Within this paradigm, imperfections merely prevent the system from settling into the ideal equilibrium of economic theory.

But a more radical departure is needed, Prof Zhang writes, where this ideal equilibrium does not even exist. The very concept of “equilibrium” does away with the fact that economy is always in flux, that unpredictable innovations can totally disrupt the economic landscape. What people actually think and do impacts the economy and changes the very parameters of the optimization problem that agents are supposed to solve. The subprime crisis should have been a minor shock. Instead, it spiraled into a self-fulfilling trust collapse. Consumers postponed purchases and firms postponed investments, driving the economy into the Great Recession. Imperfections are not a small perturbation to an otherwise ideal world; they are, on the contrary, central to both creative and destructive disruptions. We need a synthesis between Schumpeter and Soros, perhaps with a tinge of Andrew Lo and Nassim Taleb, and inputs from physics, biology, and computer science.

Prof Zhang is one of the most creative statistical physicists of his generation. He is primarily known for the so-called KPZ equation that, together with Mehran Kardar and Giorgio Parisi, he invented in 1986 to describe random surface growth.³ This triggered an enormous amount of activity both in the physics and mathematics communities, crowned by Martin Hairer’s Fields Medal in 2014. His seminal *Minority Games* counts as one of the real successes of the nascent field of econophysics.⁴

The present book was in the making for many years, and many of us were eager to read Prof Zhang’s insights. The result came as a kind of surprise: far from being a technical book promoting conceptual models that may compete with those of classical economics, this book focuses on the big picture, sowing ideas that need to be developed into a proper theory. Zhang the physicist seems to have been superseded by Zhang

the philosopher, strongly influenced by his double Chinese–Western culture and by exposure to the information economy through his tenure at Alibaba. His insights on recommendation systems, on the value of information, and on the new types of information asymmetry are particularly relevant and noteworthy.

In truly inspiring books there are many more questions than answers. I certainly hope that some of the paths opened in this book will lead to important developments in the future—maybe by Prof Zhang.

Preface

In the final decades of last century, physics, especially theoretical physics, attracted many young students, and I was among them. It was an exciting period, as amazing discoveries ranging from the subatomic world to the universe came in succession. About the turn of the century, physics seemed to be a relatively mature science, and a crowd of theoretical physicists looked to other interdisciplinary fields for new excitement. Obviously, physicists' new love for complexity is no accident: Steven Hawking has famously predicted that the twenty-first century would be the "century of complexity," instead of the century of biology or physics.

In theoretical physics we were accustomed to getting results fast, but little did I know that what I took on as a side journey wandering into finance and economics would turn out to be a much harder nut to crack. Just one problem has absorbed me for more than twenty years, and it is far from being completed. Had I known that economic problems are so hard, I am not sure that I would have had the courage to do it again!

If people find mainstream economics unsatisfactory, I believe that it is not that economists have done a bad job, but that theirs is a much harder science compared to physics. To understand, for example, financial markets with thinking agents is far more challenging than to study a gas of obedient atoms.

The challenge is still ongoing, but a first coherent picture has already emerged which allows me to present my investigation in a book for the public. During my ordeal, many disjointed analyses and isolated insights suddenly appeared in a coherent structure following the main theme on the role of information in the markets. I shall not dwell on my untold many hesitations and wrong turns that are buried in many yellowed notes. Over the years I have also released several earlier versions of this book in various formats for small circulation.

During the past two decades I have had the good fortune to interact with many economists, business leaders, startup entrepreneurs, and data scientists. About a decade ago, at the instigation of Mr Chunxiao Liang, then the senior vice president of Alibaba Inc, I helped establish an entity called Alibaba Research Center for Complexity Sciences to study

information's role in consumer markets, and I have enjoyed privileged access to many Alibaba top executives, including Jack Ma. I could closely observe how Alibaba enabled millions of consumers and vendors to do ecommerce, and talk to many frontline people in various divisions. I have learned much from them, not only of the ecology of ecommerce, but also of their views on local and global competition, current and future.

My new theory is not a direct confrontation against mainstream economics; rather, it starts from a similar ground with the supply–demand relation amended with the explicit role of information, then covers what is omitted by mainstream economics. After all, economics was conceived in another age much ahead of the current economy. Since then, Information Technology has enabled many new business models which have transformed the markets in many ways that could not be foreseen more than a century ago. Now it is also time to transform our understanding of the economy based on a modern perspective.

In the mainstream theory of consumer markets, it is still about dual relationships—buyers and sellers—and the information's role, if any, is an afterthought. In a sharp departure from previous theories, this book deals with three-way relationships: buyers, sellers, and information intermediaries (matchmakers). Three-way relationships herald a whole new perspective regarding the markets, and the book's title represents this glaring contrast.

I must explain why the word “matchmaker” appears so prominently in this book. Traditionally, matchmaking is about how to make marriage-minded men and women pair with each other. Many people get married by finding their partners without the service of matchmakers, but a small fraction of people do use a matchmaker's service. Using marriage as a metaphor, I consider consumers and businesses as the potential mates to be paired. We may have the impression that they find each other by themselves, but if we look closer we may realize that the majority of the deals are facilitated by third parties. There is a broad category of such third parties that I generically call “information matchmakers”, who in one way or another enable the two sides to find each other. In today's markets the information load is so overwhelming, both for consumers and businesses, that it is almost impossible for them to completely forego the service of such matchmakers. While for the marriage market the service of matchmakers is often unnecessary, we shall see that in consumer markets matchmakers are ubiquitous, as

most of them are uninvited and hence remain invisible. Collectively, the visible and invisible matchmakers are vital for our consumer markets and beyond. In a broader sense, we shall see that the concept of matchmakers extends to other institutions facilitating all types of positive-sum games; indeed, the win-win-win proposition is the main theme throughout this book.

It may seem that merely adding information to the supply-demand relationship is an academic task, but for a systematic account of information's role in the markets we need to consider agents' information capabilities, and these depend crucially on how matchmakers operate. We shall see that once we add these third parties, other questions arise naturally, such as information ecology in the markets, human agents' motivations, connections, social structures, and institutions, all of which are part and parcel of a viable theory of markets.

I expect that readers will be able to relate their own experience and knowledge and use this book as a stepping stone to ponder small and large issues of our consumer markets and beyond.

I wish to acknowledge the following people for their criticism, encouragement, and help. Brian Arthur, (the late) Per Bak, Jean-Philippe Bouchaud, Berno Buechel, Damien Challet, Yongchao Duan, Steve Keen, Chunxiao Liang, Linyuan Lv, Matus Medo, Andrzej Nowak, Paul Omerod, Luciano Petronero, Brigitte Rosewell, Canzhong Yao, Wuyang You, Ming Zeng, Lei Zhou, and Tao Zhou. I must acknowledge the support of my family during the labor on this book: father Yingtai, mother Xueying, wife Tetyana, daughter Gaia Nicole, and brother Jun.

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Introduction

The world economy has seen dramatic changes since the Industrial Revolution, and its focus has now shifted from smokestack to information. Mainstream economics has been the dominant theory, and the growing mismatch between theory and the real world calls for alternative explanations. Instead of offering one more critique, this book aims to build an alternative economic theory in which information plays the central role.

Information does not figure prominently in mainstream textbooks. The key parameters are prices and quantities, and people are assumed to know the quality of products. This is a far cry from the real world in which a consumer faces many choices, and it is far from easy to know the quality and suitability of products. On financial markets, information limitations are even more severe. A stock cannot simply be represented by its price, earning ratio, and a few other parameters, as there are numerous idiosyncratic details for each stock that investors must investigate.

At the core of mainstream economics is the paradigm of allocation of scarce resources, which aims at optimization under fixed constraints. Princeton economist Dani Rodrik, in his popular blog,¹ succinctly described mainstream economics: “Here is a bunch of firms, here are their choice variables, here is the market structure under which they operate, here is what they maximize, and here is what the equilibrium will look like.” Indeed, if the variables and constraints were given, the only reasonable thing to do is maximization, and economic problems would indeed reduce to mathematical exercises such as those we often see in economics textbooks and literature.

While Rodrik’s statement is plausible, we shall show that it misrepresents the real world. Facts cannot simply be labeled as variables, since they are known to only a limited number of people, and each of those who do know has a partial understanding. To achieve any goal (for example, maximization) the process takes time, during which the market constraints rarely remain fixed. Constraint-shifting invalidates

the mainstream methodology, *ceteris paribus*. In sharp contrast, our theory presents a dynamic approach that regards the constraints as movable; instead of the final state we shall focus on endless processes and investigate their causes and consequences.

Our theory is based on a new paradigm that combines allocation and creation of resources. The economy is full of allocative and creative actions, and the role of competitors (allocative) and that of innovators (creative) often mingle. The allocation paradigm focuses on optimization under constraints, and the allocation-creation paradigm studies why and how the constraints shift. In the real world, most processes towards a perceived goal will redefine the constraints.

Resources creation is not confined in a black box. Lionel Robbins once told George Soros,² then his student, that the task of economics is to study the relation between supply and demand; economists should not probe what is underneath. The new paradigm will focus on the underneath, since explicit variables and implicit knowledge are intimately connected.

For material resources, the more that are used the fewer remain; for economic opportunities in the twenty-first century, the more that are exploited the still more may be revealed and created. Instead of diminishing returns, the new paradigm considers an open evolution leading to an ever more complex world filled with unexpected opportunities and concomitant risks. Economic history is not one of repeated optimization, and wealth does not emerge by magic. How we allocate current resources will impact on future resources creation; in the economy, we can never have a fixed box within which we solve optimization problems.

Mainstream economics portrays consumer markets as having two types of participants: buyers and sellers. But in advanced economies, buyers and sellers do not sufficiently know the other side, hence we speak of ubiquitous information deficiency and the necessary rise of information intermediaries (matchmakers). Most of intermediaries, however, are not recognized as such, as they often perform the match-making role on the side. When the two sides (consumers vs. businesses) are joined by third parties, the three-way relationship gives rise to many fascinating and complex scenarios, we can only outline the main features in this book. Third parties appear in myriad disguises and span the whole spectrum from consumers to businesses. Our methodology allows us to study their strategies and evaluate the effects.

This book's key defining feature is the view of markets as three-way relationships vs. the mainstream view of dual relationships. Here we present the layout of this book, and also see why the subject warrants a systematic discussion far beyond the markets themselves and why one chapter calls for the next as the main logic develops.

Strictly speaking, if we want a new account of consumer markets highlighting information's role to the supply–demand law, Chapter 1—a narrative summarizing a dozen published papers—would suffice. Why do we need the following nine chapters? They need an apologia to justify the book's length.

In Chapter 1 we show that information capabilities can impact market transactions. Instead of just waiting for these capabilities to rise or fall as a fatality, we show that there are means and motives to change them. But consumers cannot handle the information burden alone. Third parties can either help or exploit them. Chapters 2 and 3—one focusing on the present and the other on the near future—discuss the role of information intermediaries or matchmakers, and how third parties can play a pivotal role in consumer markets. Chapter 3 is actually a prediction of an enabler of future consumer markets.

Chapter 4 discusses the consequences of Chapters 1–3: that enhanced information capabilities lead to product diversification. If this assertion turns out to be valid, then economic growth will not only be measured by GDP increases but also by product diversification.

Chapter 5 and 6 extend the same logic to two other markets: finance and information content. Besides the two important markets per se, by discussing their common features with the consumer markets we may gain insights into the common theory and the detailed mechanisms of different types of markets.

But we cannot stop after these three types of market. In Chapter 7 we discuss how markets and the economy evolve. People are often tempted to compare economic evolution with Natural Evolution. Just as Natural Selection is the agent for biological evolution, here we identify informational selection as the agent for economic evolution. Whereas the basic principles are similar to Darwinian theory, we show that economic evolution has many important particularities. The detailed mechanisms may stimulate diligent readers to ponder deeper questions concerning the economy as a whole.

Chapters 8 and 9 discuss human motivations and the implications for society. These are inspired by psychology and social studies. We posit

that the ultimate source of economic growth is from the ever-increasing wants and skills of human agents, that informational selection picks them up and institutions connect them, so that one fraction of these wants and skills convert into supply and demand.

Chapter 10 summarizes the main theme of this book by noting that we actually follow a new paradigm that may again compare with the allocation paradigm of mainstream economics. In a way, only Chapters 1 and 10 afford a direct comparison with mainstream theory. The former establishes an amended supply–demand relation, and the latter summarizes the new methodology. Chapters 2–9 concern the details of how the new paradigm might work in the real world.

By reading this book, entrepreneurs, financiers, policymakers, and the public at large might relate their own experiences and insights and reflect on their own role in the dynamic, vibrating economy. They may either refute the conclusions proposed in this book, or improve them, or add their own.

PART 1

**INFORMATION AND CONSUMER
MARKETS**