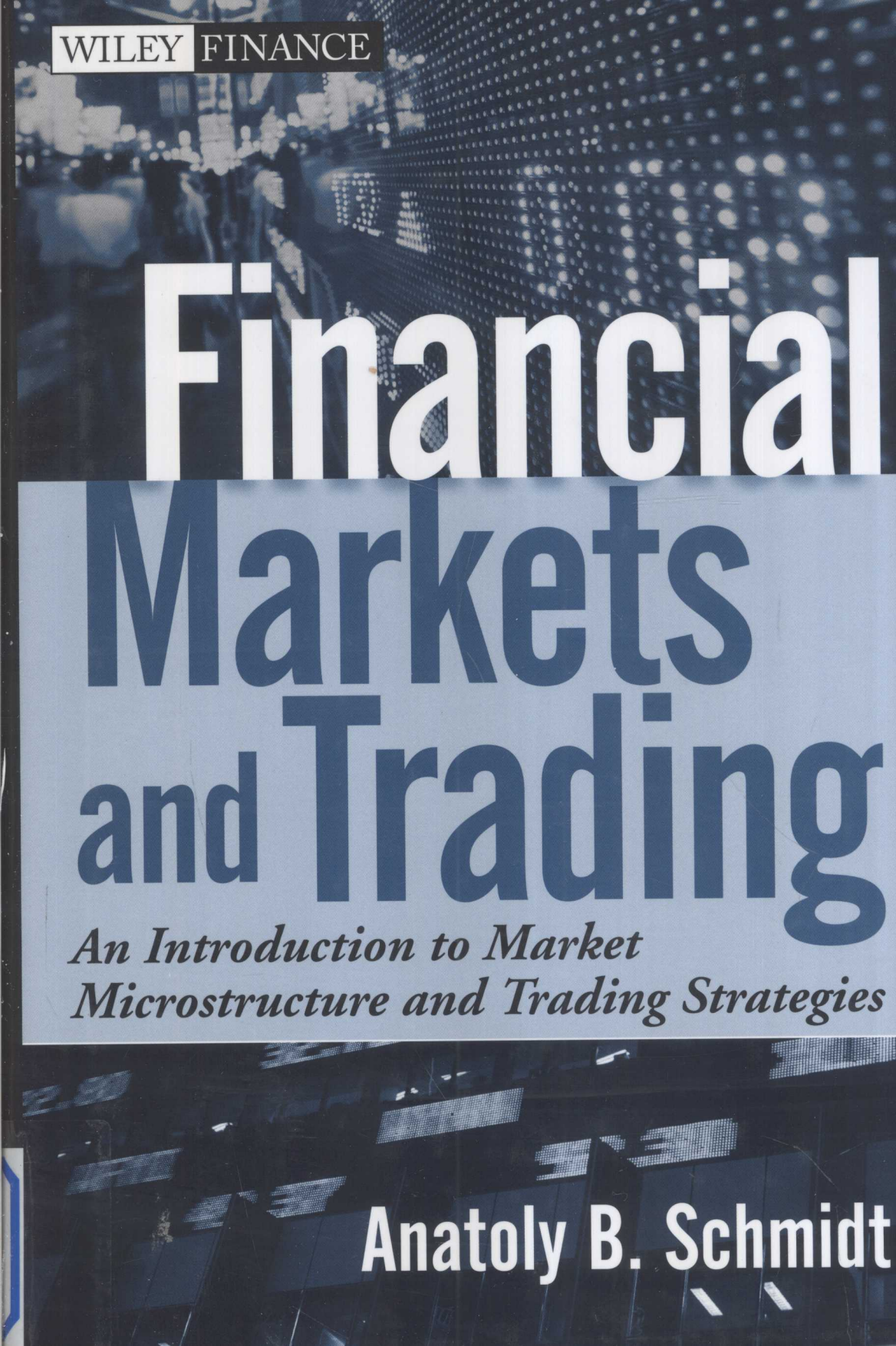
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Financial Markets and Trading
An Introduction to Market Microstructure and Trading Strategies
Anatoly B. Schmidt

Financial Markets and Trading

An Introduction to Market Microstructure and Trading Strategies

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藏书章

ANATOLY SCHMIDT

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Financial Markets and Trading

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Preface

The idea of writing this book came to me as a result of conversations with participants of meetings on quantitative finance and algorithmic trading, and with several generations of students doing internships in my group. I realized that there was a need for a single book that describes how modern financial markets work and what professional trading is about—a book devoted to the market microstructure and trading strategies.

The market microstructure theory has been an established field in finance. It has been thoroughly described in the graduate-level courses by O'Hara (1995), Hasbrouck (2007), and de Jong & Rindi (2009). Also, Harris (2002) has offered a detailed account on financial markets for practitioners. In the last decade, the landscape in this field has dramatically changed due to revolutionary changes in trading technology and the proliferation of electronic order-driven markets. The first goal of this book is to offer an overview of modern financial markets and the theoretical concepts of the market microstructure.

Trading is a process closely interwoven with the market microstructure. Indeed, in O'Hara's (1995) pioneering monograph, the market microstructure is defined in the following way: "While much of economics abstracts from the mechanics of trading, microstructure theory focuses on how specific trading mechanisms affect the price formation process." According to Harris (2002), market microstructure is "a branch of financial economics that investigates trading and the organization of markets." Also, de Jong & Rindi (2009) relate the market microstructure to the "process of financial price formation" and emphasize the importance of the market organization. Hence, while trading is widely discussed in the academic literature on the market microstructure, it is perceived primarily as a process of price formation. Yet, trading means much more for those who have ever traded for a living, for investing, or just for fun. The subject of trading strategies as a knowledge domain can be defined as studies of decision making on what, when, and how to trade. Much of its contents has been contributed by practitioners and may contain some subjective elements. Trading strategies have also received notable attention in academy, which has produced important methodological findings. Most of these results are

scattered in periodical literature. The second goal of this book is to provide an overview of the main concepts and methods used in deriving and back-testing trading strategies.

This book is for any reader who is interested in the theoretical aspects of the market microstructure and trading. It can be used by students of undergraduate finance programs and may also be useful for masters-level courses in financial engineering and mathematical finance. I have tried to offer a balance between the theoretical aspects of the market microstructure and trading strategies that may be more relevant for practitioners. I have also included in the Appendix the basic elements of time series analysis and probability distributions, which are used in the presentation of the main material.

The book is organized into three parts:

Part I (Chapters 1 to 6) is an overview of modern financial markets for equities, FX, and fixed income. I start by introducing various types of traders, orders, and market structures, and then present the major market microstructure models. Finally, I describe some important empirical properties of modern equity and FX markets.

Part II (Chapters 7 to 9) addresses the basics of market dynamics, including statistical distributions, dynamics, and volatility of returns. I discuss the efficient market hypothesis and possible predictability of returns. I also introduce the concept of agent-based modeling of financial markets.

Part III (Chapters 10 to 13) is devoted to trading. It offers a summary of the concepts used in technical analysis and statistical arbitrage as well as a more detailed description of trading performance criteria and back-testing strategies. Finally, I discuss the ideas used in optimal order execution, such as optimal order slicing and the taker's dilemma.

Specifically, the book is structured as follows:

Chapter 1 gives a general description of financial markets. I describe the different types of traders and orders. Then, I introduce different market structures including quote- and order-driven markets, and continuous and call auctions.

Chapter 2 provides an overview of modern U.S. and European equity markets including major exchanges and alternative trading systems. I also introduce institutional FX and U.S. fixed income market structures. Finally, I go over the popular and somewhat controversial (in 2010) topic of high-frequency trading.

Chapters 3 through 5 are devoted to the main market microstructure models. In particular, in Chapter 3, I describe the inventory models including the risk-neutral models—Garman's (1976) model and Amihud-Mendelson (1980) model—and the Stoll's (1978) model with risk aversion. I introduce the informational models—the Kyle's (1985) model and the Glosten-Milgrom

(1985) model—and their extensions in Chapter 4. Both inventory and informational models address the dealers markets. I review several models for limit-order markets—the Cohen-Maier-Schwartz-Whitcomb (1981) model, the Foucault (1999) model, the Parlour (1999) model, and their extensions—in Chapter 5.

Chapter 6 focuses on empirical market microstructure. First, I describe the Roll's (1984) model, the Glosten-Harris (1998) model, and the Hasbrouck's (1991, 2007) structural models, which are often used for interpreting empirical data. Then, I review intraday trading patterns, the specifics of order flows, and market impacts in equity markets and FX markets.

In Chapter 7, I provide an overview of statistical distributions and dynamics of returns. I address the problem of return predictability by reviewing the efficient market hypothesis and various types of the random walk. Then, I describe recent empirical data on statistical distributions of returns. Finally, I outline the concept of fractals and its applications in finance.

In Chapter 8, I focus on the volatility of returns. In particular, I provide an overview of various conditional heteroskedasticity models. Then, I describe current approaches to estimating the realized volatility. Finally, I outline the methods for measuring market risk.

In Chapter 9, I introduce the concepts of agent-based modeling of financial markets. I describe various trading patterns in terms of agent behavior and give an overview of two major families of agent-based models: (1) adaptive equilibrium models and (2) non-equilibrium price models.

Basic technical trading strategies are described in Chapter 10. I discuss the main concepts in chart trading, including trend-, momentum-, and oscillator-based trading strategies. I further introduce the head-and-shoulder pattern as an example of the complex geometric patterns that have gained popularity in technical trading.

Chapter 11 is devoted to arbitrage strategies. First, I give an overview of the main types of hedging strategies. Then, I focus on pair trading, which has a straightforward formulation in terms of the econometric concept of cointegration. Discussion of arbitrage risks concludes this chapter.

Back-testing of trading strategies is addressed in Chapter 12. First, I list the key performance criteria of trading strategies. Then, I provide an overview of the major resampling techniques (bootstrap and MCMC). I also introduce the random entry protocol that can be used for resampling coupled time series. Finally, I focus on the protocols for comparing trading strategies: White's (2000) bootstrap reality check and its extensions.

Chapter 13 is devoted to order execution strategies. First, I describe the benchmark-driven execution schedules (VWAP, TWAP, and other). Then, I focus on cost-driven execution schedules including the risk-neutral and

risk-averse strategies. Finally, I describe the problem of choosing the order type (taker's dilemma).

There are two appendixes at the back of the book. Appendix A provides reference material on basic statistical notions and statistical distributions that are frequently used in finance. Appendix B describes the main concepts of time series analysis: autoregressive and moving average models, trends and seasonality, and multivariate models (vector autoregressive models).

The topics covered in this book are described using multiple sources. Though I made an effort to indicate the authors of new ideas in the field, most references are provided for further reading rather than for comprehensive chronological review. My choice of references to technical trading strategies and to time series analysis, which are extensively covered in the literature, is inevitably personal.

The following notations are used in the book interchangeably: $X(t_k) \equiv X(t) \equiv X_t$, $X(t_{k-1}) \equiv X(t-1) \equiv X_{t-1}$. $E[X]$ is used to denote the expectation of the variable X. The conditional probability of event Y given event X is denoted with $Pr(Y|X)$. Variables in the bold format refer to matrices and vectors.

The views expressed in this book are mine and may not coincide with the views of my former and current employers. I would greatly appreciate readers' comments, which can be sent to me at a_b_schmidt@hotmail.com.

ANATOLY B. SCHMIDT

Acknowledgments

Writing this book was my personal affair, about which few people knew. Craig Holder encouraged me to work on this project. Bill Falloon, Wiley's editor, took a risk by accepting it for publication.

I am grateful to members of the academic community for sharing with me their expertise. My special thanks go to Peter Hansen, Blake LeBaron, and Bruce Mizrach. Needless to say, all possible drawbacks of this book remain my sole responsibility.

Alas, my father Boris passed away before he could have seen this book. If I am able to crunch numbers, this comes from my dad. Boris did not have an opportunity to exploit his gift for math: He became an orphan while fleeing from Nazi-occupied Latvia to Russia and started working at the age of 16. My mother Ida taught literature for more than 40 years. I learned from her how to spend nights at my desk.

I am grateful to my wife Sofia and my children Mark and Sabina for their love and patience. I also constantly feel that they need me—and that's what helps me keep the pace.

Alec Schmidt

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PART

One

Market Microstructure

CHAPTER 1

Financial Markets: Traders, Orders, and Systems

This chapter describes a big picture of financial markets: who the traders are, what types of orders can be submitted, how these orders are processed, how prices are formed, and how markets are organized.

TRADERS

Let us start with the people who trade. They are called (well, you guessed it) *traders*. Those who trade for their own money (or their employer's money) are *proprietary traders*. Their ultimate goal is to make profits by buying low and selling high, whether it is long-term investment or day trading. Other traders execute orders for their clients. They are called *brokers* or *agency traders*. To denote the institutional character of a broker, the term *brokerage (firm)* is also used. For brokers, profits from trading may not be important since they receive commissions for trading and other services from their clients. Typical brokerage services include matching the clients' buy and sell orders, connecting to markets, *clearing* and *settlement*, providing market data and research, and offering credit. Most of the listed services are self-explanatory, but clearing and settlement may need some elucidation. Settlement is delivery of traded assets to the trading counterparts (buyers and sellers). The trading process (sometimes called the *transaction*) does not occur instantly. For example, settlement in the spot foreign exchange for most currencies takes two business days. Clearing denotes all brokerage actions that ensure settlement according to the market rules. These include reporting, credit management, tax handling, and so on.

The institutions that trade for investing and asset management (pension funds, mutual funds, money managers, etc.) are called the *buy-side*. The *sell-side* provides trading services to the buy-side. Besides brokers, the sell-side

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