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978-0-521-19589-8 - Commodity Price Dynamics: A Structural Approach

Craig Pirrong

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COMMODITY PRICE DYNAMICS

Commodities have become an important component of many investors' portfolios and the focus of much political controversy over the past decade. This book utilizes structural models to provide a better understanding of how commodities' prices behave and what drives them. It exploits differences across commodities and examines a variety of predictions of the models to identify where they work and where they fail. The findings of the analysis are useful to scholars, traders, and policy makers who want to better understand often puzzling – and extreme – movements in the prices of commodities from aluminum to oil to soybeans to zinc.

Craig Pirrong is Professor of Finance and Energy Markets Director for the Global Energy Management Institute at the Bauer College of Business at the University of Houston. He was previously Watson Family Professor of Commodity and Financial Risk Management at Oklahoma State University and a faculty member at the University of Michigan, the University of Chicago, and Washington University. Professor Pirrong's research focuses on commodities and commodity derivative pricing, the relation between market fundamentals and commodity price dynamics and the implications of this relation for the pricing of commodity derivatives, derivatives market regulation, commodity market manipulation, and the organization of commodity markets. He has published more than thirty-five articles in professional publications and is the author of four books. He has consulted widely with financial exchanges around the world, testified before Congress on energy pricing, and served as an expert witness in a variety of cases involving commodity markets. He holds a Ph.D. in business economics from the University of Chicago.

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Preface

This book weaves strands of research that date back more than 20 years, to approximately 1990–1991. Although I worked at a futures commission merchant (that is, a brokerage firm) while in graduate school, that work involved financial futures exclusively. Deciding to leave that business in mid-October 1987 (thereby causing the 1987 crash), first for a stint in litigation support consulting and then on to academia at the Michigan Business School, I worked on research completely unrelated to futures markets. But in spring and summer 1989, the Italian conglomerate Ferruzzi cornered the soybean market in Chicago. The corner, and the Chicago Board of Trade's response to it, resulted in sharp criticism of the exchange. To address this criticism, the CBOT decided to commission an academic study of the grain market delivery mechanism.

My senior colleague at Michigan who was primarily responsible for bringing me there, the late Roger Kormendi, succeeded in wrangling a grant from the CBOT to carry out the study. He walked into my office and said: "I know nothing about commodity markets. You worked in them. Would you be part of the team on this study?" I responded: "Well, I know nothing about commodity futures, but I'm game to learn."

This nudge completely changed the trajectory of my research, and virtually everything I have worked on since relates to commodities and derivatives in one way or another. My formal training is as an industrial organization economist, and so my research initially focused on trying to understand the causes and effects of market power in commodity markets and commodity derivatives. Classical manipulations – corners and squeezes, such as the Ferruzzi episode – are exercises of market power, so I examined in detail how various economic "frictions" such as transportation costs could affect a particular market's vulnerability to market power.

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I was particularly interested in how to detect manipulations, for the purpose of improving the ability of the courts and regulators to deter manipulation. It has long been known that market-power manipulation distorts price *relationships*, notably the relation between forward (or futures) prices on the same commodity with different maturities. For instance, Ferruzzi's exercise of market power raised the price of July 1989 soybean futures relative to the price of September 1989 soybean futures. But, to identify distortions, it is necessary to understand how "normal," undistorted prices behave in a competitive market. Thus began the inquiries that have culminated in this book.

When I began my research, there were basically two theories on offer, both somewhat confusingly called the "theory of storage." One invokes the concept of a "convenience yield" to explain why forward prices in commodity markets often fail to cover the costs of holding inventories even when inventories are positive. The other uses dynamic programming methods that explicitly incorporate the real-world constraint that inventories cannot be negative to derive implications about the behavior of commodity prices in a competitive market with rational expectations.

The convenience-yield concept struck me as an ad hoc way to rationalize an empirical regularity. The dynamic programming-based approach struck me as more rigorous, with more well-developed microfoundations. The dynamic programming methods were also familiar to me, having been exposed to them in Robert Lucas's macro courses at Chicago. Consequently, I concentrated my research efforts on these models.

There was a flurry of publications in this area around this time (the early to mid-1990s), including work by Deaton and Laroque and that by Williams and Wright. This work clearly laid the foundation for my research, and I gratefully acknowledge having learned a good deal from it. But its focus on low-frequency (e.g., annual) prices, its relative lack of attention to higher moments of prices, and correlations between forward prices with different maturities left unexploited many important sources of data. They also did not exploit fully the potentially quite informative cross-sectional variation in commodity markets: corn and copper are very different things, with different production and consumption patterns and drivers, and such differences are potentially quite revealing sources of information that can be used to test commodity pricing models.

My background in finance, and in options pricing in particular, made me quite attuned to the importance and informativeness of higher moments. Consequently, I focused my attention on this issue, first in empirical work

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with my former Michigan colleague Victor Ng, then in more theoretical work based on the dynamic programming approach. It is that work that is the basis for most of the material in this book.

My finance background also exposed me to some computational techniques, notably finite difference methods, used in option pricing that are routine in finance but which have seldom been employed in commodity pricing models. The book embodies a fusion between the methods commonly employed in the dynamic programming literature and the quantitative methods routinely employed in options pricing.

I hope that the book conveys several important lessons.

First, the structural approach provides valuable insights into the drivers of commodity prices. One novel insight explored in Chapter 5 is that it is necessary to incorporate stochastic volatility of *fundamentals* to explain salient features of commodity price dynamics. This is a finding that points out the value of looking at higher moments of prices and at the prices of derivatives other than forwards and futures – notably, options of various types.

Second, the structural approach informs as much through its failures as its successes. The chapter on seasonal commodities (Chapter 6) demonstrates that the conventional approach cannot explain salient aspects of price dynamics – most important, price correlations. This should motivate a search for improvements and extensions of the approach; Chapter 6 offers a few suggestions along these lines, but much more needs to be done. The current binding constraint on progress is computational but, fortunately, that is a constraint that is easing steadily over time.

Third, the structural models make quite plain the value of looking beyond prices alone and incorporating data on quantities – especially inventories – into any empirical analysis of commodity markets. After all, the role of prices is to guide the allocation of resources, so it is natural – but all too uncommon – to incorporate data on actual resource allocations in any empirical examination of the theory. Because forward prices guide the allocation of resources over time, and because inventories are a way of shifting resources through time, it is particularly revealing to incorporate inventory data into any analysis. This is also true to the origins of the academic study of commodity markets. The first major scholar in this area, Holbrook Working, was particularly interested in the relation between differences in the forward prices for commodities with different maturity dates (i.e., futures spreads) and the amount of commodity in storage.

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I envision three audiences for this book. The first, of course, is scholars engaged in research on commodity markets and commodity prices, and graduate students looking for a self-contained and fairly comprehensive treatment of the subject.

The second is practitioners, most notably those in commodity trading and risk management. I believe that the material in the book provides an intellectual framework that can help traders understand the fundamental factors that influence prices and how they do so. Even the model failures can be helpful: they help identify potentially important factors omitted from the models, and it is useful to understand the known unknowns. I also expect that even though it is presently impractical to utilize the fundamentals-based structural models for pricing contingent claims as a replacement for Black-type models (except for, perhaps, electricity), this will not always be the case. Improvements in computational power, and improvements in data available to estimate and calibrate the models, hold out the prospect that structural models may someday replace reduced-form models as the preferred way to price commodity options of all types.

The third is policy makers. Commodity prices have always been a bone of political contention, although the intensity of commodity-related controversies has waxed and waned over time. The years since 2005 or so have been a time of waxing. Commodity price spikes and crashes have sparked widespread condemnation of the malign effects of speculation in commodities, and this condemnation has resulted in regulatory and legislative action. As of the present time (November 2010), the U.S. Congress has directed regulators to impose limits on commodity speculation and the European Union has made constraining commodity speculation a policy priority.

Too often, debates over the effects of commodity speculation have not been grounded in a scientific understanding of how the commodity prices are determined and how these prices behave. The models in the book can help provide such a grounding. For instance, Chapter 5 on stochastic fundamental volatility shows that some apparent anomalies are in fact quite consistent with rational pricing. Moreover, the emphasis on the importance of looking at quantities as well as prices is invaluable in identifying distortions. Because prices guide the allocation of resources, if prices are distorted, quantities should be distorted too. The models in the book help characterize how prices *and quantities* in undistorted markets should behave, thereby making it easier to identify distortions that may justify a policy intervention.

Because this book represents the work of decades, there are many people to whom I owe a debt of gratitude for making it possible. Professionally, I have profited immensely from collaborating with my co-authors Victor Ng

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and Martin Jermakyan. They taught me a great deal, and I hope that some of what they taught me shines through every page. Our work demonstrates how complementary skills and knowledge can produce something that is bigger than the sum of its parts. I am also grateful to many practitioners who have shared their wisdom, experience, and insight with me. Two who had a very great impact on my thinking as I was just beginning my explorations of these matters were Frank Sims, then of Cargill, and Paul Krug, first of Continental Grain and subsequently of ADM Investor Services.

I am also very appreciative of the support of the various schools where I have had the privilege to serve as a faculty member. My current academic home, the Bauer College of Business of the University of Houston, deserves special notice. I deeply appreciate that Dean Arthur Warga and Finance Department Chair Praveen Kumar understand the value and relevance of research on commodity markets in a finance department and have supported my research accordingly.

One individual deserves particular thanks. My thesis advisor and mentor, Lester Telser, is an amazing scholar who has made contributions to myriad areas of economics, including industrial organization, the theory of the core, and even macroeconomics. But his first major contribution was in the area of commodity futures pricing. He has taught me so much about so many things, including commodities. It is gratifying to be able to make my own contribution to a subject that he helped pioneer.

Finally, I owe so much to my family for their inspiration, support, counsel, and guidance over the years. My parents, Kay and Glenn, and my wife and children, Terry, Renee, and Genevieve, are my metaphorical bookends. My parents instilled in me a love of learning and scholarship and provided invaluable educational opportunities that made an academic career possible. Terry and the girls gave me the support and encouragement and understanding – and the time – that are so vital to scholarly endeavors.

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