Real Options and Merchant Operations of Energy and Other Commodities

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## Real Options and Merchant Operations of Energy and Other Commodities

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## Abstract

The value chain for energy and other commodities entails physical conversions through refineries, power plants, storage facilities, and transportation and other capital-intensive infrastructure. When the operation of such commodity conversion assets occurs alongside liquid markets for the input and output commodities, the operating flexibility of conversion assets can be managed as real options on the underlying commodity prices. Merchant operations is an integrated trading and operations approach that (i) buys and sells commodities to support market-value maximizing operating policies and (ii) values conversion assets, for capital budgeting and trading purposes, based on the cash flows such policies produce. This monograph provides a unique integrated finance and operations perspective on the topic of merchant operations. In particular, this monograph introduces the concept of merchant operations; presents the basic principles of option valuation; surveys foundational models of commodity and energy price evolution; analyzes the structure of optimal operating policies for commodity

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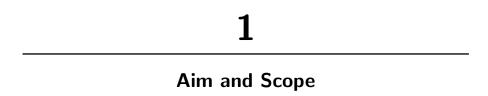
conversions, focusing specifically on inventory and other intertemporal linkages in storage, inventory acquisition and disposal, and swing assets; considers a variety of heuristic storage operating policies; and discusses future trends in this multidisciplinary area of research and business applications. In honor of the late Professor Paul R. Kleindorfer

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Commodity conversion assets perform various transformation processes, including the production, refining, industrial and commercial consumption, and distribution of physical commodities and energy sources, such as grains, metals, electricity, coal, crude oil, and natural gas. This monograph deals with the management and valuation of conversion assets. Commodities and energy are traded on physical markets. It is thus natural to approach the management of commodity conversion assets from a merchant perspective, which adjusts the level of the conversion activities to profit from the dynamics of commodity prices. We introduce the expression *merchant operations* to describe this approach.

Implementing merchant operations to maximize the market value of commodity conversion assets is a complex task. It requires both models of the evolution of commodity prices and stochastic optimization models of the conversion activities. The existence of traded contracts on commodities and energy sources allows commodity conversion assets to be interpreted as real options on the prices of the underlying commodities. This real option interpretation greatly facilitates formulating the necessary mathematical models.

## 2 Aim and Scope

The valuation of real options shares the same theoretical foundations as the valuation of financial options. However, the real options that arise in the context of merchant operations are distinguished from financial options by one or more of the following features: (i) decisions at multiple dates, (ii) intertemporal linkages across decisions, (iii) multiple underlying variables, (iv) payoffs determined by operational costs and contractual provisions, (v) engineering-based constraints on operating decisions, and (vi) quantity decisions rather than binary exercise/no-exercise decisions. American and Bermudan financial options also involve decisions at multiple dates with intertemporal linkages, but the other features in this list are largely unique to merchant operations. Intertemporal linkages are particularly important in merchant operations and are related to inventory, the scale of operations, and delays and costs incurred when switching between operating modes. Moreover, even when the structure of an optimal operating (exercise) policy can be explicitly characterized, determining such a policy typically involves numerical computation and approximations. Closed-form solutions are rare in merchant operations, while they are more widespread for financial options.

The aim of this monograph is to present the basic tenets of merchant operations, that is, the management of commodity conversion assets as real options on commodity prices. The scope of this monograph is on the foundational principles that underlie the valuation of real options, on basic models of both the evolution of commodity and energy prices and commodity conversion assets, and on optimal and heuristic operating policies with a focus on commodity storage assets.

A unique aspect of merchant operations is the integration of financial and operational management aspects. This monograph reflects this integrated perspective. Section 2 introduces commodity conversion assets and merchant operations. Sections 3 and 4 discuss the valuation of commodity options and models of the evolution of commodity and energy prices, respectively. Sections 5 and 6 describe the merchant management of commodity storage assets. Section 7 deals with inventory disposal/acquisition and swing assets. Future trends in merchant-operations research and applications are discussed in Section 8.

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