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Commodity Procurement with Operational and Financial Instruments

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Jan Arnold

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1 Introduction

1.1 Motivation

Increasing global competition and cost pressure force enterprises and supply chains to discover undetected cost-saving potentials. In particular, interfaces to the procurement market are a promising field for improvement. Recent developments in international trade outline the high influence of uncertain deliveries and highly volatile prices on the companies' costs. A vital question in research, industry, and politics addresses the optimal procurement policy of raw materials due to uncertain future prices and is of highest priority for the firms' success and even the wealth of a nation. Nowadays, commodity markets and commodity derivative markets offer transparent, fast, and efficient trade and risk sharing for raw materials and financial products on raw material prices, e.g., option contracts. This coexistence of operational and financial procurement instruments, i.e., buying opportunities on spot and derivative markets, offers an auspicious chance to optimize the procurement policy in the crucial problem of raw material procurement which is the focus of this thesis.

The most basic distinction of commodities is between storable and non-storable commodities (see Pirrong (2008)). The vast majority of commodities is storable, mainly at some costs, but this class is fairly heterogeneous. Commodities can be characterized by seasonality in demand (such as crude oil or natural gas) or production (take wheat or sugar as example) or contrarily by a rather continuous production and consumption (e.g., nickel and aluminum).

The recent economic developments have strongly increased the attention researchers, managers, politicians, and even private households pay on the development of raw material prices (see Der Spiegel, 24/2008.). Several raw materials, among them the most important as copper, iron ore, tin, aluminum, crude oil, wheat, soybeans, sugar, or coffee, are traded at commodity exchanges and therefore, a financial market is existent. Derivatives as futures or option contracts are available. For example, the London Metal Exchange offers future contracts for various metals such as aluminum, copper, tin, or lead with a term of 3, 15, or 27 months. As other examples, the New York Mercantile Exchange offers option contracts on copper and the Chicago Board of Trade derivatives on Ethanol,

Livestock, and plenty of others. Many fields of essential importance in daily life are affected directly by the price level of raw materials, e.g., the costs for energy, heating, or fuel as illustrated in Figure 1.1 for one of the most important commodities, crude oil. Due to a highly industrialized agriculture, prices of basic food and

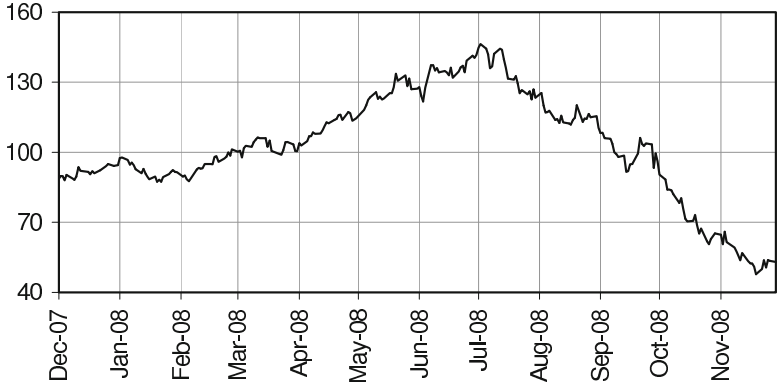

Figure 1.1: Quotations of Brent Crude Oil [US-$/Barrel]

agricultural products nowadays are almost as volatile as the crude oil price. An increasing global population increases demand for agricultural products. On the other hand, soil sealing and alternative usage of cultivable land decrease available acreage which cannot fully be compensated by technological innovations. Nevertheless, prices of agriculturals are of crucial interest for many, especially developing, countries. Figure 1.2 provides the price of wheat as representative for several key agricultural products (e.g., soybeans, coffee, orange juice) in order to illustrate the recent price development. The success of the heavy and processing industry is not only influenced by energy costs, but also by costs for main ingredients as copper, aluminum, or steel, which are usually produced and consumed rather continuously. To give an impression of the development of non-precious metal prices, Figure 1.3 maps the quotation of aluminum prices.

Certainly, far not all raw materials are traded at commodity exchanges but on dedicated markets which are quite often organized as over-the-counter markets. Reasons can be found in a lack of standardization (e.g., steel), due to storage and transportation difficulties (natural gas), or due to few market participants on the demand and/or supply side (benzene).

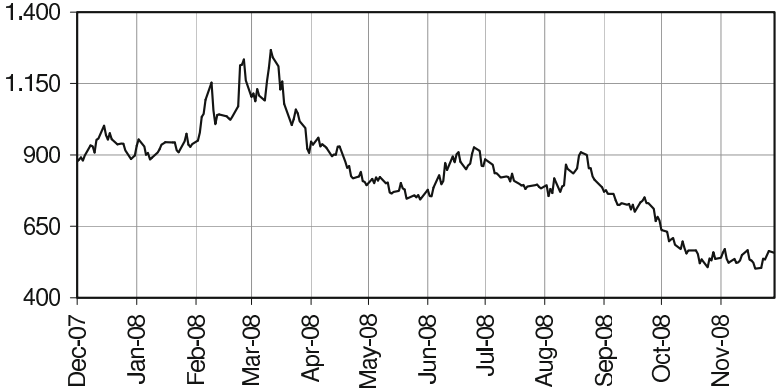

Figure 1.2: Quotations of Wheat Futures [US-Cent/Bushel]

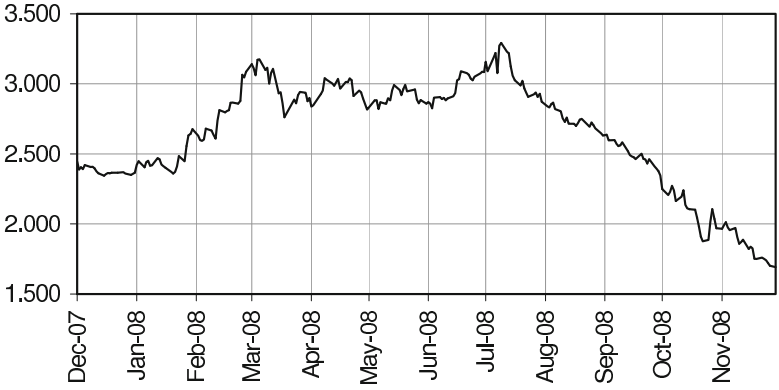

Figure 1.3: Quotations of Aluminum [US-$/Tonne]

Nowadays, more than 2.000 steel sorts (see DIN EN 10027-1) are distinguished. A single sort quite often does not have a sufficient trade volume to justify its trade at an exchange. Recently, the London Metal Exchange has made first efforts developing futures contracts for steel (see Campopiano (2007)). Nevertheless, these relatively new instruments have not yet fully been established. Steel consumers

regularly set up long-term contracts with their suppliers specifying a certain volume within a certain period or simply fixing a price for a certain period in advance. Likewise, options on pre-specified volumes are usual.

Natural gas is usually transported via pipelines which provide a regionally limited availability. Although recent technological innovations have made techniques for gas liquidation efficient and workable (see Younger and Eng (2004)), the argument of storage and transportation difficulties still is sufficiently strong to prevent natural gas to be traded at exchanges. (Private) gas consumers therefore depend one unilateral price fixing of the suppliers which take the crude oil price as indicator for the price fixing.

Although the worldwide trading volume of Benzene is relatively high (e.g., about 8.5 billion metric tons in West Europe in 2007 (see CMAI (2008)) only few suppliers and consumers arrange the trade mainly among each others. The need to set up a public quotation at an exchange is low as trade agents, e.g., Platts or Dewitt, publish historical quotations and established a system of average prices serving as guideline for transactions. This system is the basis for trading option contracts, similar to standardized derivatives, which require an individual agreement of both contractual partners.

Summarizing, numerous commodities are traded at commodity exchanges such as the Chicago Board of Trade or the London Metal Exchanges. These exchanges offer a quotation of commodities' spot prices and match supply with demand. An increasingly important business area are derivatives on the commodities such as futures or call and put option contracts which are comparable to derivatives offered at stock exchanges. Similar contracts are usual at dedicated over-the-counter markets. This choice offers potential of improvement for a firm's procurement policy, but requires research considerations from an operational and a financial viewpoint. The young research field at the interface of finance and operations is increasing researchers' attention due to undetected potential of improvement. Combing the fields of operations and finance enables to raise emersed benefits by connecting the strengths of both disciplines. To highlight the importance of combined research in operations and finance and to give guidelines for research, Birge et al. (see Birge et al. (2007), p. 355.) state:

"Two basic implications of the seminal work of Modigliani and Miller [see Modigliani and Miller (1958)] are that the management of the firm's operations can be separated from its financial management, and that hedging the variability of the cash-flows associated with the firm's operations adds no value to the shareholders. Largely as a consequence of these fundamental conclusions, the fields of Finance and Operations Management have independently developed during the last half of the past century. While illuminating, the Modigliani-Miller theory rests

on a number of simplifying assumptions, whose violations make the interface between Operations Management and Finance relevant. [...] It is now timely to compile state-of-the-art research at the interface of Finance and Operations Management [...]. Such research will capitalize on the richness of the two fields while exploiting gaps left in their interfaces [...]."

1.2 Research Questions

The purpose of this thesis is multi-fold. The key question is the optimal procurement strategy of a buying agent who can match his demand just-in-time or in advance via inventories or financial option contracts. The thesis is at the interface between the disciplines of operations management and finance. The research questions contain the aspects of timing the purchase and determining the order quantity. This is studied within deterministic continuous time models using the theory of optimal control in order to isolate dynamic effects. Additionally, the aim is to answer the question how to optimally combine the procurement instruments, i.e., how to mix operational and financial instruments. This aspect is studied in two-period stochastic models under the assumption of a perfect commodity market involving arbitrage-free raw material prices in order to isolate stochastic effects.

One key research question addresses the optimal manufacturing and procurement time and quantity when cost and demand parameters are deterministic and dynamic. A continuous time modelling approach is appropriate to answer this question. In detail:

- Which combination of inventories and JIT-procurement is optimal?
- In how far is the optimal manufacturing/procurement decision influenced by dynamic prices?
- Which trade-off is responsible for the optimal manufacturing/production quantity and the timing of this decision?

The question of the optimal mix of procurement instruments under uncertain future demands and prices when advance procurement via inventories, the procurement of call option contracts, and JIT-procurement is possible is answered by a two-period stochastic modelling approach. In detail, the research questions involve the following aspects.

- How are the procurement instruments inventory holding, option contracts, and JIT combined optimally? Under which circumstances does one of these procurement instruments dominate an other one?