



Innovative Applications of O.R.

Global facility network design in the presence of competition

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ABSTRACT

We study the facility network design problem for a global firm that is a monopolist seller in its domestic market but faces local competition in its foreign market. The global firm produces in the face of demand and exchange rate uncertainty but can postpone localization and distribution of the output until after uncertainties are resolved. The competitor in the foreign market, however, enjoys the flexibility of postponing all production activities until after uncertainties are resolved. The two firms engage in an ex-post Cournot competition in the foreign market. We consider three potential network configurations for the global firm. Under a linear demand function, we provide the necessary and sufficient condition that one of the three networks is the global firm's optimal choice, and explore how the presence of foreign competition affects the sensitivity of the global firm's design to various cost parameters and market uncertainties.

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1. Introduction

1.1. Problem motivation

As firms are expanding the reach of their supply chains globally they are facing increasing exposure to drastic demand shifts, volatile currency fluctuations, and intensifying competition in developing markets. In the chemical industry, for example, the weakening of U.S. currency in recent years has played an important role in DuPont's international growth, accounting for 12.0% of its growth in Europe, 4.0% in Asia Pacific, and 7% in Canada and Latin America. At the same time, local competitors in emerging economies have been quickly improving quality while retaining low cost, becoming formidable competitors in those markets (Gutierrez, 2008).

Responding to changes in the global marketplace and anticipating more changes in the future, firms are pressed, from time to time, to revisit their global supply chain design and consider plans that change their manufacturing footprints: closing and opening capital intensive production facilities, downsizing and increasing production levels, and establishing more supply linkages between facilities and markets in different countries. In the past decade many U.S. companies have moved production activities to Asia and parts of Europe where raw material and labor costs have been significantly lower. However, sharp changes in global economic conditions in the past two years have started to undermine several factors that used to favor the offshoring trend (Goel et al., 2008).

Specifically, as the highly volatile oil price increased from \$28 a barrel in 2003 to nearly tripled in 2008, raw material and transportation costs rose in a similar magnitude. Wage inflation in China and Europe and weak U.S. currency have significantly reduced the labor cost advantage of manufacturing previously offered by those regions. Products that were once produced profitably offshore to supply the U.S. market are now more attractively produced nearby in Latin America countries. Dong et al. (2010) described in detail a polyvinyl butyral manufacturer's consideration of establishing capital intensive production in emerging markets and how these decisions were affected by cost factors such as production and transportation costs, and demand and exchange rate uncertainties.

This paper focuses on the most challenging decisions in the global facility network design: investment in core production facilities that can be used to satisfy common market requirements in the face of uncertainties in demand, exchange rate, and global competition. We consider a stylized model in which a global firm sells to two markets: its domestic market and a foreign market. The global firm is a monopolist in its home market, but faces competition in the foreign market from a local incumbent. The global firm, in order to meet requirements from different markets in a timely fashion, performs its core production (common across products targeted for different markets) in the face of uncertainties, postpones localization to the needs of the two markets and distribution until after uncertainties are resolved. We assume that the global firm has ample processing capacity for localization and distribution activities. The global firm's key network design decisions are: In which of the two markets to locate its core production facilities and the corresponding output level of each. We consider three

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potential network configurations: (1) domestic centralization, under which a production facility is located in the domestic market to supply both markets, (2) foreign centralization, under which a production facility is located in the foreign market to supply both markets, and (3) complete network in which each market has its own production facility that can supply both markets. The local incumbent in the foreign market pursues a local strategy and focuses on the local market only. Its local knowledge and close connection with local suppliers enable it to act more swiftly to capitalize the market opportunities. Therefore, the global firm and the local incumbent are endowed with different flexibility to cope with changes in market conditions (see Hill, 2012, Chapter 13: *The Strategy of International Business*). Global companies such as Nokia and Procter & Gamble Co. and Chinese locals such as Lenovo and Huawei have experienced this type of competition: while the global firm tailors the product offering to emerging market needs and adjusting its capability to serve the local market often requires coordination with suppliers in other parts of the world, the local competitor enjoys the rapid production development cycles and make quick customizations for customers (Donoghoe et al., 2012).

Fig. 1 illustrates the three network choices of the global firm. We provide the necessary and sufficient condition for each of the three considered networks to be optimal. In light of Dong et al. (2010) study on the facility network design decision of a monopolist global firm, we explore how the presence of the competition affects the global firm's optimal production output and facility network configuration. A quick preview of our insights follows.

First, we explore the impact of the relevant cost changes on the global firm's optimal output in the presence of competition in the foreign market. Most interestingly, we find that the global firms optimal output does not necessarily decrease as its foreign competitor becomes more cost efficient. A cost efficiency improvement of the foreign competitor results in more fierce competition in that market, and instead of decreasing output, the global firm may benefit from increasing its production output and allocation to the foreign market to discourage the foreign firm from selling to that market.

Second, we find that the impact of the demand and exchange rate volatility on the global firm's optimal output can be different from the monopolist case. The monopoly global firm exploits the demand volatility by increasing its optimal centralized output. In contrast, in the presence of competition in the foreign market, the global firm's optimal centralized output may decrease due to the more fierce competition inspired by the demand volatility. The exchange rate volatility has a different effect. In the presence of competition, the global firm competes more aggressively in the foreign market by increasing its optimal production output with increases in the exchange rate. In contrast, without the com-

petition, the global firm is always the monopolist on the foreign market, and the global firm's foreign market profit decreases faster when being translated to its home currency as the exchange rate increases. Consequently, the monopoly global firm may decrease its optimal output as exchange rate becomes more volatile.

Finally, we study the impact of the competition on the global firm's choice of global production networks. If the global firm currently centralizes core production in its foreign market where the competition takes place, the global firm can effectively cope with the increasingly fierce competition by adjusting its capacity; if the global firm currently produces in both countries, it is more effective to close the foreign production and concentrate on producing only from the domestic market.

1.2. Literature review

Our work is related to the research of global operational strategies. In this literature, one stream of research focuses on the optimal use of operational flexibility under an assumed global facility network design. We refer readers to Van Mieghem (2003) and Kouvelis and Su (2007) for recent literature reviews on papers dealing with the use of operational flexibility or operational hedging in global supply chains. The other stream, to which this paper contributes, examines the optimal facility network design, taking into account the optimal use of the resulting operational flexibility. In this section, we provide a brief review on this later stream of research, and we further categorize it by the competitive setting being modeled as: a newsvendor network with exogenous price, the firm is a monopolist with ex-post pricing flexibility, and the firm competes with another firm and prices ex post (see Table 1).

Van Mieghem and Rudi (2002) proposed a modeling framework for a general multi-product, multi-processing and storage-point network in which the input-output transformation technology was linear and product revenue and cost structures were linear and given. They showed that the optimal inventory (capacity) investment decision for such a network was the solution to a multi-dimensional newsvendor problem and the tradeoffs driving the decision could be interpreted as underage and overage costs in the multi-dimensional demand space, and thus the coined name "newsvendor network." The newsvendor network has been applied by several recent works that studied inventory (capacity) investment in the multi-product and multi-market environment. Facility network design requires another layer of decision: whether to establish a processing or storage point in a network. Lu and Van Mieghem (2009) addressed this question for a two-product, two-market newsvendor network and derived the necessary and sufficient condition for centralizing common component production in one market versus dividing production in two markets. They showed that whether to centralize component production

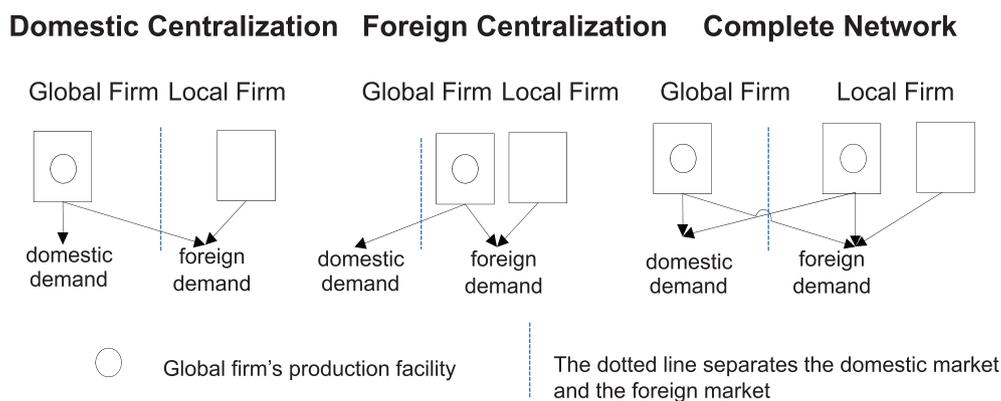


Fig. 1. The global firm's three network choices.

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