# International Production Network Planning

By: David Cheung, Ross Pieper
Advisors: Jarrod Goentzel, Tim Russell
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Summary: A multinational chemical company is looking to include duties and duty credits as consideration factors in its production planning. This undertaking requires understanding of not only domestic trading laws but also international trading laws and how trading blocs can affect them. The company's products are manufactured and shipped across different regions of the world. In almost every stage of its supply chain, it is exposed to some form of tariffs and credits. In this paper, the researchers present a mathematical optimization model that aims to help the company to achieve production efficiency for one of its agricultural business units while accounting for duties and duty credits. Analysis includes scenario simulations to test different rates of duties, different locations of production facilities, and different sourcing countries. The results suggest that depending on the circumstances mentioned, duties and duty credits can become significant parts of total production costs.
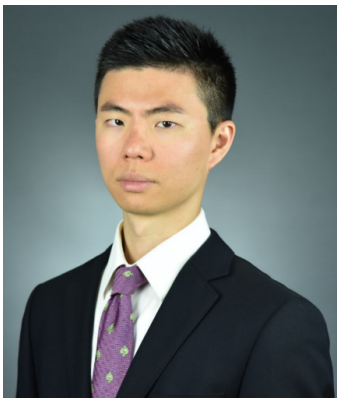
Prior to MIT, David Cheung worked as a natural gas trader at BNP Paribas, an investment bank. He received his Bachelor of Science from New York University Stern School of Business.

Prior to MIT, Ross Pieper worked as a logistics project manager at Land O' Lakes, an agricultural cooperative. He received his Bachelor of Science from University of Minnesota.

KEY INSIGHTS

1. Duties and duty credits are rarely considered in production planning optimization models.

2. Duty and duty credits can have large impacts on production planning decisions.

3. Considering duty and duty credits can lead to substantial cost savings for multinational companies.

Introduction

In today's globalized environment, multinational companies have more options than ever before to design their production networks. In addition, their choices have more bearing on their degree of competitiveness. Sourcing and production decisions are no longer confined to local factors. Instead, to optimize the global production, multinational companies have to adopt an integrated perspective that examines their entire supply chain networks holistically. In particular, duties, duty credits, and other forms of trade barriers must now be considered in addition to standard cost such as labor, production, and transportation. The research's sponsor company requested the development of a mathematical model to incorporate duties and duty credits in production planning.

Operational Context and Objective

The sponsor company is a multinational chemical producer. In particular, the researchers focus on an agricultural business unit of the sponsor company.

This unit specializes in the production of active ingredients, herbicides, insecticides, fungicides, seed solutions and other specialty solutions. The unit has two production plants. One is in Puerto Rico and the other is in Brazil. Both plants are capable of producing the same 49 SKUs and collectively service customers from 19 different countries.

Currently, production planning of the business unit is performed locally without a holistic supply chain approach. The business unit operates on a production plan that was conceived through manual simulations.

The researchers were tasked to provide an optimization model that the agricultural business unit can use to evaluate its production strategies between the two plants. The model must minimize total costs that consist of labor, transportation, production, duties, and duty credits while meeting all demand requirement of the unit's customers. The decision variables in the model are the amount of finished products that each plant should produce and also the amount the amount of raw materials that each plant should source from the different supplier.

Within this context, the flows that were considered include, from the suppliers to the two plants and from the plants to the customers. Ultimately, the optimized solution would be compared to what the business unit is currently doing to show the benefits of optimization, as well as the importance of including duties and duty credits.

Data Sources and Methodology
The business unit of the sponsor company provided the researchers data such as production, costs, raw material conversion costs, sourcing nations, demand nations, transportation costs, and relevant duty rates.

The overall effort of this research is to determine whether production of various SKUs can be geographically affected by the consideration of duties and duty credits. To conduct the analysis, the researchers looked into different duty laws associated with the trading bloc and country associated with each plant. The Puerto Rico plant is located within the trading bloc governed by NAFTA and the Brazil plant is located within the trading bloc governed by Mercosur.

The method that the researchers used to approach the task is a linear optimization model.

Objective function: minimize z

$$z = \sum_i \sum_j \sum_g C_{ij} X_{ijg} +$$
$$\sum_z \sum_n \sum_j E_{znj} Y_{znj} +$$
$$\sum_n \sum_j d_{nj} + \sum_j \sum_g f_{jg} +$$
$$\sum_i \sum_j \sum_g l_{ijg} X_{ijg} +$$
$$\sum_z \sum_n \sum_j w_{znj} Y_{znj} -$$
$$\sum_z \sum_i \sum_n \sum_j \sum_g c_{zinjg}$$

Constraints:

Effective Duties on Raw Materials Constraint

$$d_{nj} \geq \sum_z B_{znj} d_{znj} Y_{znj} \ \forall n,j$$
$$d_{nj} \leq M(1 - T_{nj}) \ \forall n,j$$

Effective Duties on Finished Products Constraint

$$f_{jg} \geq \sum_i V_{ijg} f_{ijg} X_{ijg} \ \forall j,g$$
$$f_{jg} \leq M(1 - S_{jg}) \ \forall j, \text{g}$$

Effective Duty Credits Constraint

$$c_{zinjg} \leq B_{znj} d_{znj} \frac{X_{ijg}}{R_{zij}} \ \forall z,i,n,j,g$$
$$c_{zinjg} \leq M T_{nj} \ \forall z,i,n,j,g$$
$$c_{zinjg} \leq M S_{jg} \ \forall z,i,n,j,g$$

Demand Constraint

$$\sum_j X_{ijg} = D_{ig} \ \forall i,g$$

Raw Material Conversion Constraint

$$\sum_z \sum_n R_{zij} Y_{znj} \geq \sum_g X_{ijg} \ \forall i,j$$

Non- Negativity Constraints

$$X_{ijg} \geq 0 \ \forall i,j,g$$
$$Y_{znj} \geq 0 \ \forall z,n,j$$

Binary Constraints

$T_{nj} = \{0,1\}$

$S_{jg} = \{0,1\}$

Definitions:

Decision Variables

X_{ijg} = number of units of product i made in plant j for demand nation g

Y_{znj} = number of units of raw material z from source country n to plant j

Variables

d_{nj} = costs of duties of moving raw materials from country n to plant j

f_{jg} = costs of duties of moving finished products from plant j to demand nation g

c_{zinjg} = amount of duty credits eligible of moving raw materials z from country n to plant j, which is also dependent on the movement of finished product i from plant j to demand nation g

Constants

D_{ig} = demand of product i for demand nation g

C_{ij} = cost per unit of product i made at plant j

V_{ijg} = intercompany transfer cost per unit of product i from plant j to demand nation g

E_{znj} = cost per unit of raw material z from source country n to plant j

B_{znj} = intercompany transfer cost per unit of raw material z from source country n to plant j

R_{zij} = ratio of raw material z to product i at plant j

l_{ijg} = logistics costs of product i from plant j to demand nation g

w_{znj} = logistics costs of raw material z from source country n to plant j

d_{znj} = duty cost of raw material z in percentage from source country n to plant j

f_{ijg} = duty cost of product i in percentage from plant j to demand nation g

M = big M, a large positive number

Binary Variables

T_{nj} = whether country n and plant j belong to the same trading bloc

S_{jg} = whether plant j and demand nation g belong to the same trading bloc

By providing this mathematical model, the business unit has the option to compare the production plan that is currently being applied to what is the optimal solution. In addition to providing a tool for comparison, the model also gives visibility to the way duties and duty credits affect supply planning.

Findings and Discussions

The mathematical model that the researchers developed is only about 1% more cost effective than the current production plan that the business unit created through manual simulation. In part, this can be attributed to the fact that the cost difference between making products at one plant versus the other is not very large for most products. More importantly, duties and duty credits being a small portion of total costs also dwarfed the impact of considering them.

To illustrate the positive potentials of the mathematical model, the researchers conducted multiple sensitivity analysis. Scenarios include changing duty rates of raw materials and finished products, imposing duties to only one plant, and forcing one plant to service all demand.

Conclusions

Through the different scenarios the researchers tested, they found that duties and duty credits have a large impact on production planning models when they duty rates are high. This is especially true when the duty rates of raw materials are high because raw material duties are eligible for credit if they meet certain criteria. This realization led the researchers to conclude that the business unit of the sponsor company should be including duties and duty credits within its production planning models.

Furthermore, duty laws are constantly changing based on relationships of foreign governments, hence even if considering duties and duty credits in the production planning model may not make a big difference now, there is a potential that they could make a big difference in the future. To best adapt to this uncertainty is to make proper and intelligent preparation by having the right framework.