



# Optimal material ordering policy and allocation rule for a manufacturer making multiple products



Wei Xie<sup>a</sup>, Haitao Liao<sup>b</sup>, Baozhuang Niu<sup>a,\*</sup>

<sup>a</sup>School of Business Administration, South China University of Technology, Guangzhou, Guangdong 510640, China

<sup>b</sup>Department of Industrial Engineering, University of Arkansas, Fayetteville, AR 72701, USA

## ARTICLE INFO

### Article history:

Received 19 March 2017

Revised 26 October 2017

Accepted 20 November 2017

### Keywords:

Flexible production system

Multiple products

Ordering policy

Allocation rule

Analytical solution

## ABSTRACT

Material ordering and allocation are important decisions for manufactures making multiple products, because those firms usually possess flexible production systems which can produce different products based on the same raw material. In this paper, we investigate the ordering policy (OP) and allocation rule (AR) of the raw materials for a manufacturer selling multiple products. The manufacturer's decision-making problem is analyzed under three scenarios: (1) joint decisions on OP and AR, (2) fixed AR, and (3) predetermined OP. We show that the latter two are not special cases of the first scenario, and they require different solution methods. Our objective is to derive the optimal solutions *analytically*. For the first scenario, we obtain the closed-form solution that is indeed optimal for the non-concave profit function. For the fixed AR scenario, the products with twice-differentiable demands are studied, and the exact optimal OP for the raw material is achieved. Finally, if the OP is predetermined, we prove that the profit function is concave in AR and provide the associated optimality conditions, for which the optimal AR can be reached numerically. Different from the pervious heuristic approaches, these mathematically tractable solutions are easy to be applied by the practitioners.

© 2017 Elsevier Inc. All rights reserved.

## 1. Introduction

With the development of modern agriculture, the agricultural companies are forced to manage their supply chains more efficiently [1]. According to a call for research in agribusiness problems [2], a particular challenge faced by the food and agribusiness sector is that how to appropriately assess and respond to the demand and supply variations, which will affect the agricultural companies' costs and profits significantly. Evidently, in the recent years, the risk of making and selling agricultural products has shown an increasing trend. According to the report of World Economic Forum 2009, the low efficiency in the food value chain causes at least a \$100 billion annual loss in the U.S. Essentially, the maximization of total profit considering the uncertainties is the ultimate goal of modern agriculture, in both developed and developing economies [3].

For agricultural companies, a commonly seen phenomenon is that a firm, who acts as a processor, orders a raw material (e.g., meat, corn, and potatoes) from its contracted suppliers (farms) and uses a flexible production system to turn the single material into multiple products. One can observe that the agricultural economists have established the analysis for the

\* Corresponding author.

E-mail addresses: [bmwxie@scut.edu.cn](mailto:bmwxie@scut.edu.cn) (W. Xie), [liao@uark.edu](mailto:liao@uark.edu) (H. Liao), [bmniubz@scut.edu.cn](mailto:bmniubz@scut.edu.cn), [niubaozhuang@qq.com](mailto:niubaozhuang@qq.com) (B. Niu).

production flexibility, which is associated with the farm specialization [4]. Though, the production line provides flexibility in making different products, due to the demand uncertainty, the firm has to tackle the difficulty in making decisions on the material order quantity and the production quantities of different products. In practice, a typical example is the production system of dairy products. The system can utilize a single material, i.e., milk, to process a variety of dairy products, such as butter, nonfat dry milk, and cheese. A regular problem faced by the process factory is how to satisfy the uncertain demands of these dairy products. Similar examples can be found in the agricultural sector, e.g., cotton can be used to make multiple clothing products with different designs and colors and wheat is a major ingredient to make bread, porridge, biscuits, and doughnuts. In particular, to maximize the profit, both material procurement and production planning decisions must be made based on demand forecast and cost estimation for leftovers or unsatisfied demand. By taking the procurement and production issues into consideration, we are motivated to study the “one-material-multi-product” production system for the related agricultural companies.

In this paper, we examine the process system that manufactures multiple non-substitutable products. For example, the products such as bread, butter, nonfat dry milk, and doughnuts, are usually belong to different product categories, which have no downstream competition. The problem is modelled under a single-period multi-product setting. Under these assumptions, we mainly focus on the optimal ordering policy (OP) and/or the allocation rule (AR) of the raw materials for the agricultural companies. Specifically, we consider three scenarios for the one-material-multi-product system, i.e., (1) joint decisions on OP and AR, (2) fixed AR, and (3) predetermined OP. Note that there are three scenarios in total, because the decisions only have two parts (OP and AR).

In the first scenario, the OP and AR are considered simultaneously and the associated profit function is assumed to be twice differentiable. The main challenge to obtain the analytical solution for this scenario is that the profit function is generally not concave. Because of this, traditional concavity analysis is not applicable. However, we are able to propose an alternative approach, which derives the optimal solution in closed form for this problem; For the second scenario, we assume the AR is fixed and the firm should determine the OP accordingly. The proposed single-variable problem is concave, and the optimal OP can be achieved by traditional concavity analysis. However, when the demands are bounded, the problem cannot be separated, for which we discuss the optimal OP for the unbounded uniform demand case in detail. To model the third scenario, the OP is predetermined before making a decision on AR. In this scenario, though the profit function is concave in the AR, the exact solution method has not been reported in the literature. We first introduce a Lagrangian multiplier to relax our problem to an equivalent unconstrained version. Unlike previous research, which solves the Lagrangian relaxation problems via heuristic methods, we present a sufficient condition that can be used to obtain the optimal AR analytically. Notice that the firm may not process all of the products in one period, we also study the firm’s preference in production, which may affect the profit significantly due to the unsatisfied demands. Numerical experiments are conducted to analyze the effects of some key parameters for different scenarios.

The remainder of this paper is organized as follows. Section 2 briefly reviews the related literature. A modelling framework of the proposed problem is presented in Section 3, and the analytical and numerical results for different scenarios are provided in Section 4. Finally, Section 5 concludes the work.

## 2. Literature review

Our paper is closely related to two streams of research, i.e., the agriculture supply chain management and the multi-item newsvendor models.

In the first stream of research, because of the significant impacts of agricultural economy, the production and operations issues related to agriculture supply chain have attracted considerable attention from the academia. For examples, [5] examines the production planning problems of a company that produces olive oil. In that problem, randomness exists in both demand and yield, for which the sale price and the ordering cost will be affected; [6] analyze the contract design problems between suppliers and retailers in the agricultural seed industry to deal with the associated tradeoffs. In particular, [1] provide some typical examples of agriculture supply chain management, which are mainly focused on developing countries/regions (e.g., Sri Lanka, Malaysia, Afghanistan, India, Africa, Philippines, and Bangladesh). [3] introduce an innovative business model, named ‘e-Choupals’ in India, and investigate its impact on the farmers’ production decisions. Under the framework of Cournot competition models, [7] discuss the farmers’ incentives to utilize the free demand information provided by the government. They also consider the risk of demand uncertainty to derive the corresponding optimal ordering and supply decisions. Recently, [8] presented the contract choice issues in contract farming. They studied the agricultural companies’ ordering decisions for two scenarios, i.e., with and without the farmer cooperative. For a more comprehensive review of the agribusiness decision-making problems, the readers are referred to [2].

However, the above-mentioned studies merely consider the single-material or/and single-product problems. Differs from these articles, we propose to characterize a commonly seen flexible operation mode in the agribusiness, that is, one-material-multiple-product problem. In this problem, to improve the profitability, we analyze an agricultural company’s material ordering and allocation decisions, which have been overlooked by the previous literature. Methodology wise, we also develop approaches that can be used to obtain the optimums analytically.

On the other hand, for the second related research stream, i.e., multi-item newsvendor models, the associated study can be dated back to 1960s, when [9] introduced a Lagrange multiplier technique with a dynamic programming solution procedure to derive the optimal order quantity in a single-constraint and multi-product setting. Since then, the problem has been

Download English Version:

<https://daneshyari.com/en/article/8052066>

Download Persian Version:

<https://daneshyari.com/article/8052066>

[Daneshyari.com](https://daneshyari.com)