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全球產銷供應鏈管理之節稅模式

A tax savings model for managing a global production-distribution supply chain

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中 華 民 國 九 十 八 年 六 月

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摘要

複雜的全球產銷供應鏈網路包括課稅區、國際運籌區、深層與淺層加工製造程序之區位點特性，以及運輸之節線特性。妥善地選擇節稅區位與製造程序，用以增加稅後利潤，對於全球性製造業者相當地重要。基此，本研究旨在提出幾個節稅方法，進而發展出該複雜網路下之稅後利潤最大化的節稅模式。數值實驗說明本研究提出的模式係為一有效的方法，可以讓全球性製造業者達到稅率節省之目的，而本模式也指出重要關鍵的節稅運籌行為。

關鍵字：全球產銷網路、國際運籌區、稅後利潤、節稅模式、運籌行為

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ABSTRACT

The complex global production-distribution network involves nodal location features of tax areas and international logistics zones, manufacturing procedures of simple process and deep process, as well as transportation arcs. Since choosing tax savings locations and manufacturing procedures that increase after-tax profit is important to global manufacturers, this study aims to present several tax savings approaches and to develop a tax savings model for maximizing after-tax profit in the complex network. Numerical illustration demonstrates that the proposed model is an effective approach for global manufacturers to achieve tax savings. The proposed model elucidates the crucial logistics behavior associated with tax savings.

Keywords: Global production-distribution network, International logistics zone, After-tax profit, Tax savings model, Logistics behavior

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Pei-Ju Wu

A tax savings model for managing a global production-distribution supply chain

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CHAPTER 1 INTRODUCTION

This chapter is divided into four sections: (1) background and motivation; (2) purpose and scope; (3) research procedures; and (4) chapter organization.

1.1 Background and Motivation

Global logistics can be conceptualized as the geographic expansion of domestic logistics into markets abroad (Bowersox and Closs, 1996; Sheu, 2004). Fierce competition in a rapidly changing global market has imposed tremendous pressure on manufacturing enterprises, forcing them transform and adjust their supply chain operations abroad (Chia et al., 2002). Enterprises need to incorporate fragmented logistics activities into an international business operation (Birkinshaw and Morrison, 1995; Greis and Kasarda, 1997; Porter, 1998). Albino et al. (2002) indicated that a necessary policy for managing resources is to negotiate the supply chain both at a global and a local level. Prater and Ghosh (2006) also noted that globalization permits enterprises with expanded supply chains to access and coordinate global resources. Manufacturers are increasingly capable of dealing with full system production, and currently seek to add value to existing production systems (Zhai et al., 2007). Accordingly, global manufacturers are currently integrating their operations in different countries to achieve manufacturing efficiency across markets and in units that operate worldwide (Cavusgi et al., 2004). Furthermore, facilities with both manufacturing and distribution functions can better cope with rapid changes in global logistics (Simchi-Levi et al.,2003; Sheu, 2004; DHL, 2006).

However, once goods are transferred from one place to another, complicated tax factors arise, such as import duties, corporate taxes, value added taxes, sales taxes, etc. (Goetschalckx et al., 2002; Sheu, 2003; Meixell and Gargeya, 2005; Power, 2005). Therefore, both the practitioners (such as Foxconn, Weblink International, DHL, etc.) and academics (Arntzen et al., 1995; Vidal and Goetschalckx, 2001; Fandel and Stammen, 2004; Avittathur et al. 2005; Vila et al., 2006; Balaji and Viswanadham, 2008) are actively seeking appropriate ways to save tax costs. Moreover, most enterprises using transfer prices to avoid taxation are illegal. Thus, it is worthwhile to look for legitimate tax savings approaches.

Governments recognize that most global enterprises pay a great deal of attention to the impact of tax factors on their global profit. Therefore, a common governmental strategy is to develop "international logistics zones" (Lu and Yang, 2007) offering tax-exemption strategies (e.g., exemptions from corporate tax or import duties) to attract investment and ideally to spark economic growth. Taking advantage of preferential taxation is extremely important for global manufacturers to achieve tax savings.

Nevertheless, few studies have investigated the optimal tax savings route and manufacturing procedures to increase after-tax profit for managing a production-distribution supply chain in the global network with international logistics zones.

1.2 Purpose and Scope

With the background and motivations mentioned above, the main purposes of this study are as follows:

1. To represent the concept of various tax savings approaches.
2. To develop a tax savings model for the purpose of managing a global production-distribution supply chain in the complex global production-distribution network with international logistics zones.
   (1) To maximize after-tax profits while simultaneously considering tax factors (import duties, corporate taxes, VAT) and other basic cost factors (e.g., transportation cost, inventory cost, etc.).
   (2) To determine the legal optimal tax savings route and

manufacturing procedures.

To facilitate model formulation, the study scope is postulated as follows:

1. Goods are classified in this study as modular components, semi-products and finished products.
2. Supply chain members include both internal and external members responsible for different global logistics functions. Internal supply chain members include manufacturing centers and processing DCs, while external supply chain members are vendors and brand name companies. Moreover, the number and location of all supply chain members are given. A hybrid fuzzy integral decision-making model for selecting locations can be found in Feng *et al*. (2009).

There are still some factors that affect the determination of the optimal tax savings route and manufacturing procedures in the global production-distribution network with international logistics zones, such as quotas, certificates of origin and local content that will not be discussed in this study.

1.3 Research Procedures

The research procedures are briefly explained as follows and shown in Figure 1-1.

1. Problem identification

   The first step is to identify the background, motivation, purposes and scope of this study. Herein, the research problems were derived from the first step.

2. Literature review

   The second step is to achieve an adequate understanding of the relevant literature on global production-distribution supply chains, international logistics zones and tax savings models. This step assists in understanding the development and management of a global production-distribution supply chain in the global production-distribution network with international logistics zones.

3. Problem statement

   The third step is to state the problem and clarify the scope of the study. This step also facilitates model formulation.

4. Tax savings approaches

The fourth step is to investigate key tax factors contributing towards operating income under the characteristics of international logistics zones.

5. Modeling

The fifth step is to formulate a tax savings model for the purpose of deriving after-tax solutions that are able to maximize profit in the global production-distribution network with international logistics zones.

6. Numerical illustration

The sixth step is to test the applicability and the solvability of the proposed model. Here, a simplified numerical study is out through an interview. Sensitivity analysis is used for varying tax parameters such as corporate tax rates, duty, VAT rates and VAT drawback rates. To further examine logistics behavior, three extended scenarios and their numerical results are presented.

7. Conclusions and suggestions

The seventh step is to summarize crucial findings based on the numerical results of the logistics behavior. Furthermore, the distinction between this study and previous studies are discussed as well. Finally, related issues not addressed in this study are identified for further research.

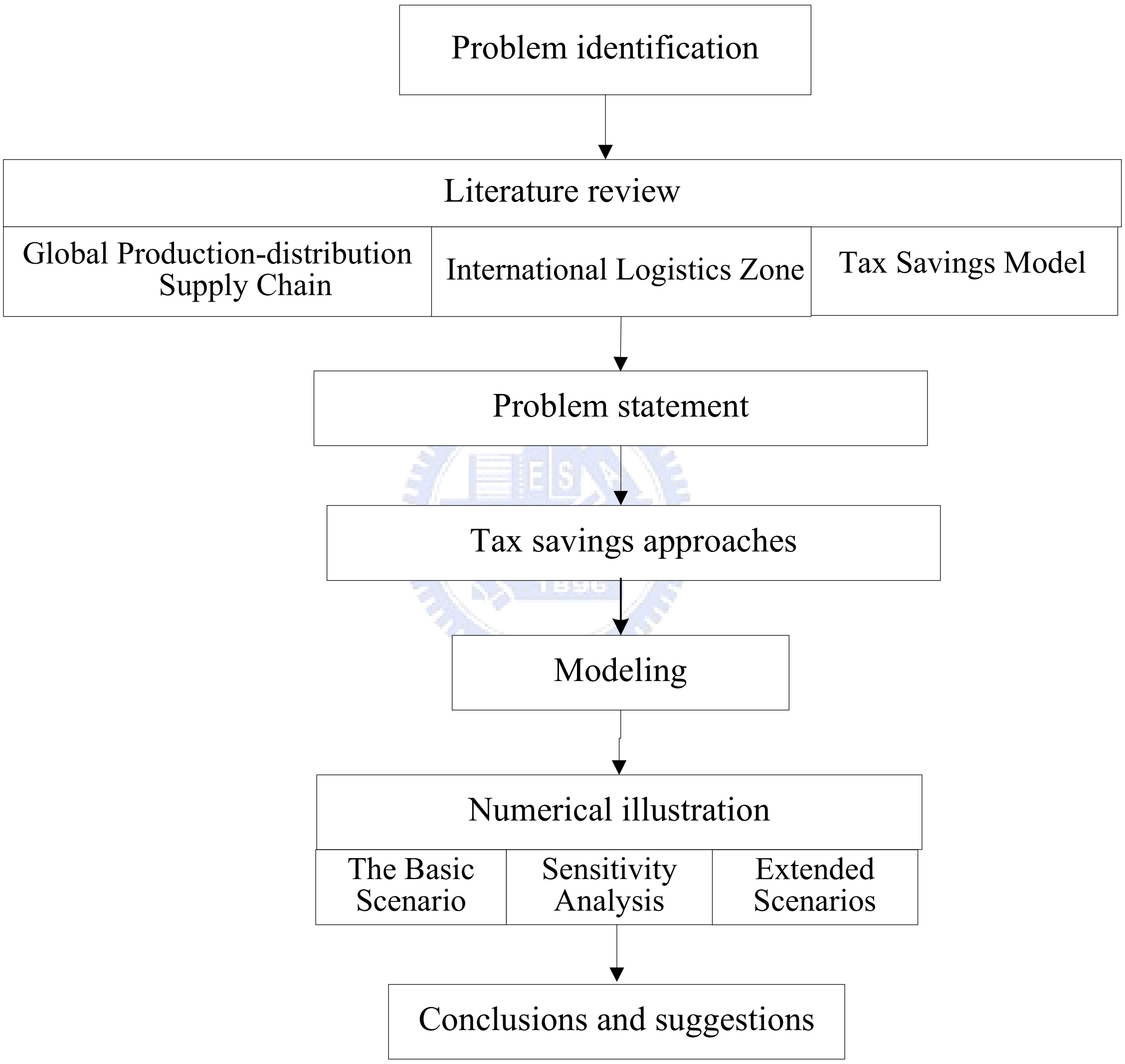

Figure 1-1 Research procedure

1.4 Chapter Organization

The rest of the study is organized as follows. Chapter two conducts a thorough review of the global production-distribution supply chain and the international logistics zone and tax savings model. Chapter three outlines the main problem studied. Chapter four describes the concept of tax savings approaches. Chapter five provides a model with tax savings, with incorporation of an emerging global production-distribution network, to find after-tax profit-maximizing solutions. Chapter six tests the effectiveness of the proposed model and discusses the findings and numerical results. Finally, Chapter seven summarizes the conclusions.

CHAPTER 2 LITERATURE REVIEW

The literature review includes the following: (1) global production-distribution supply chains; (2) international logistics zones; (3) tax savings models.

2.1 Global Production-distribution Supply Chain

In order to satisfy worldwide customer requirements, many manufacturers desire to transform their domestic logistics into global logistics. To become a global manufacturer in the present day, a manager needs to devise not only production but also distribution strategies.

Each manufacturing base only produces special ancestor goods (e.g. components) for the total demand in participating countries, and ships these ancestor goods to other manufacturing bases for further transformation of ancestor goods into descendant goods (e.g. finished products) (Arntzen *et al*., 1995; Hiraki, 1996). Consequently, a distributed product often has its manufacturing activities dispersed throughout many locations (Lakhal *et al*., 2005).

Mattsson (2003) pointed out that the globalization of manufacturers requires global coordination between distribution and manufacturing activities. Swafford *et al*. (2006) observed that enterprises can adopt manufacturing and distribution processes that reduce the influence of demand uncertainty. Boissière *et al.* (2008) argued that global supply chain management needs to consider limited production capacity and distribution costs.

Manufacturers are increasingly capable of dealing with full system production, and currently seek to add value to existing production systems (Zhai *et al*., 2007). Minimizing manufacturing cost and production time combined with the increasing quality and shipment reliability are important challenges to all production systems (Mezgár *et al*., 2000).

Specifically, manufacturers must devise effective global logistics strategies that maximize profit and fulfill customer orders within the manufacturing networks (Hammami *et al*., 2003). Hameri and Paatela (2005) also observed that contract manufacturers focus on integrating value added operations in networks to maintain and recreate profitable business in markets with narrow margins.

Enterprises can extend spatiotemporal coordination to move towards supply chain collaboration. Supply chain integration significantly affects the performance improvement of the supply chain (Frohlich and Westbrook, 2001; Petersen *et al*., 2005; Elmuti *et al*., 2008). Supply chain collaboration is especially effective in realizing an enhanced speed-to-market (Samaranayake, 2005, Soosay *et al*., 2008), as demonstrated by looking at Hyundai (Hahn *et al*., 2000) and BMW (Miles and Snow, 2007).

Model formulations and solution algorithms for the production-distribution problem have been proposed in the past (Lee and Kim, 2002; Yan *et al*., 2003; Chan *et al*., 2005; Chen and Vairaktarakis, 2005; Nonino and Panizzolo, 2007).

Vidal and Goetschalckx (1997) conducted an extensive review of strategic production-distribution models. Barbarosoglu and Özgür (1999) built the hierarchical design of an integrated production and distribution system. Björk and Carlsson (2007) pointed out that seeking the optimal manufacturing plan and the coordination of shipments with said optimal manufacturing plan is very critical and difficult.

Aliev et al. (2007) put forth a fuzzy-genetic approach to aggregate the production-distribution planning in supply chain management. Selim *et al.* (2008) developed a fuzzy goal programming approach to deal with the collaborative production–distribution planning in a supply chain.

Nevertheless, most research concerned with domestic logistics has focused on computational efficiency or special cases, which has limited the applicability of their results to reality.

2.2 Tax Savings and International Logistics Zone

Governments recognize that most global enterprises pay a good deal of attention to the impact of tax factors on their global profit. Therefore, a common governmental strategy is to develop “international logistics zones” (Lu and Yang, 2007) offering tax-exemption strategies (e.g., exemptions from corporate tax or import duties) to attract investment and ideally to spark economic growth. Examples of these logistics zones are free trade zones, export processing zones, free port zones, bonded zones, global logistics hubs and customs-free zones (Prasad and Sounderpandian, 2003; Lee and Yang, 2003; Oum and Park, 2004; Lu and Yang, 2007; Lee, 2007).

International logistics zones provide opportunities to implement functional activities involving transportation, distribution, assembly, storage, clearance, consolidation, labeling, packing, inspecting, and marketing (Lu, 2003; Sheu, 2004; Teng et al., 2007).

Lin *et al.* (2006) pointed out that many countries have instituted export processing zones, foreign trade zones, and logistics centers, and further market their finished products around the world. Lee (2007) mentioned that multinational corporations have focused logistics functions such as warehousing, distribution, and reprocessing in a global logistics hub.

For the purposes of this study, "international logistics zones" are defined as zones offering tax-exemptions, while "tax areas" are defined as areas which do not offer tax preferences. Taking advantage of preferential taxation is extremely important for global manufacturers in order to achieve tax savings. Herein, tax savings means the amount enterprises save on taxes.

Additionally, global enterprises have typically used the transfer price (Van Mieghem, 1999; Gjerdrum *et al*., 2002; Eden and Rodriguez, 2004) to manipulate profit distribution among their subsidiaries. However, this makes them easy prey for costly audits and litigation (Lakhal *et al*., 2005). Many countries now have international logistics zones that reduce taxes for global enterprises. Thus, discussing legitimate tax savings approaches associated with international logistics zones is worthwhile.

2.3 Tax Savings Model

Some of these tax factors have already been examined in previous studies. Arntzen *et al*. (1995) proposed a global supply chain model for minimizing the total cost at the Digital Equipment Corporation with consideration to duty drawbacks and duty relief.

Simchi-Levi *et al*. (2003) further noted that implementing a strategy in which the manufacturing process is completed in a local DC can reduce costs associated with duties as duties are lower for semi-products than for finished products. Accordingly, manufacturers must decide whether to: (1) import semi-products and then convert these products into finished products in tax areas to reduce duties; or (2) manufacture finished products in international logistics zones and then import the finished products to tax areas to reduce corporate tax.

Since a differential tax structure contributes to distribution network decisions that can cause logistic inefficiency, Avittathur *et al*. (2005) developed a model for determining the locations of distribution centers (DCs) which considered the impact of differential sales taxes which was applicable in inter-state trade.

Nonetheless, corporate taxes are not easily incorporated into a profit-maximizing model, mainly because some of the subsidiaries of a global manufacturer may operate at a loss. Restated, unprofitable subsidiaries are not required to pay corporate taxes, but others are subject to corporate tax. Vidal and Goetschalckx (2001) constructed a global supply chain model to cope with the above problem. Their model maximized the after-tax profit of a multinational enterprise by considering transfer pricing and transportation cost allocation.

Fandel and Stammen (2004) and Vila *et al*. (2006) extended previous research to construct an after-tax profit-maximizing model that would reflect similar tax factors such as duties and corporate taxes, with an emphasis on product life cycles and divergent process industries. Balaji and Viswanadham (2008) proposed a tax model to choose between outsourcing versus foreign direct investment (FDI) alternatives at the various stages of a global supply chain.

However, there has been little done to develop a model which simultaneously considers import duties, value added taxes and corporate taxes in a global production-distribution network with international logistics zones.

CHAPTER 3 PROBLEM STATEMENT

To clarify the study scope and facilitate model formulation, the problem statement is postulated as follows: (1) types of goods; (2) supply chain members and the flow of goods; (3) transactions.

3.1 Types of goods

Goods, ancestral to descendent, are classified in this study as modular components, semi-products and finished products. The modular strategy has been discussed in detail elsewhere (Lamothe *et al*., 2006). Figure 3-1 shows three methods of goods transformation, including transforming modular components into semi-products, transforming modular components into finished products or transforming semi-products into finished products.

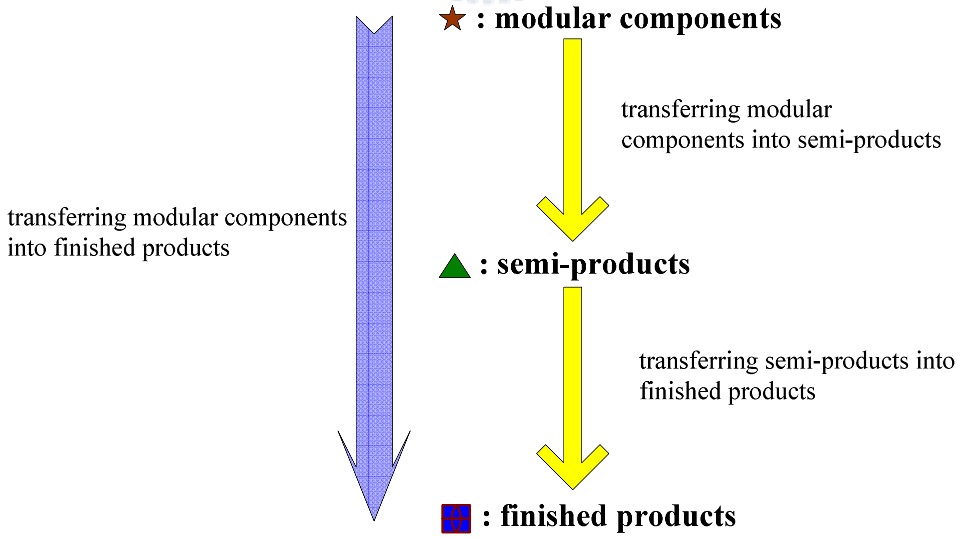

Figure 3-1 Types of goods

3.2 Supply chain members and the flow of goods

Supply chain members include internal and external members responsible for different global logistics functions. Internal supply chain members include manufacturing centers and processing DCs, while external supply chain members include vendors and brand companies. Moreover, the number and location of all supply chain members are given. Kerbache and MacGregor Smith (2004) indicated that after manufacturers link their internal processes to external supply chain members, the resulting supply chain often comprises a very large network of activities and resources. The modeling and optimization of such a complex system is very difficult.

Facilities functioning only as manufacturing centers or only as distribution centers are less responsive to rapid changes in global commerce than facilities capable of both. Simchi-Levi *et al*. (2003) pointed out that intense competitive pressure has forced manufacturers to add manufacturing capability at DCs. Sheu (2004) also noted that manufacturers with combined production and distribution facilities have significant advantages in global logistical management. Furthermore, DCs in international logistics zones can be classified as "deep process" and "simple process" facilities (DHL, 2006). Deep processing DCs have manufacturing functions proceeding with serious manufacture producing added value, while simple processing DCs cannot manufacture and merely own the functions of simple and convenient processes (e.g. assembling). For clarity, DCs serving the functions of either simple or deep processing, or both are defined as "processing DCs" in our study. In practice, DCs can be divided into three types: deep processing DCs, simple processing DCs and non-bonded DCs, depending on their locations and manufacturing procedures. Deep processing DCs located in international logistics zones have both deep process and simple process functions. Although located in international logistics zones, simple processing DCs only have the simple process function. Non-bonded DCs perform the same functions as deep processing DCs, but they are located in tax areas. Accordingly, the emerging global production-distribution network comprises nodal location characteristics of tax areas and international logistics zones, manufacturing procedures of simple process and deep process in these nodes, as well as transportation arcs.

Manufacturing centers receive modular components from vendors which are then transformed into semi-products or finished products. Then, manufacturing centers send semi-products or finished products to DCs.

The basic functions of DCs are consolidating and distributing finished products from manufacturing centers to brand companies. Nevertheless, processing DCs may also have simple, deep (or both) processing functions, depending on their location in international logistics zones or tax areas. Accordingly, DCs can be divided into three types: deep processing DCs, simple processing DCs and non-bonded DCs. As Figure 3-2 illustrates, deep processing DCs located in international logistics zones have both deep process and simple process functions. Here, deep process involves transforming modular components into semi-products, transforming modular components into finished products and transforming semi-products into finished products, while simple process involves simple processes of semi-products and finished products (e.g. transfer, assembling, and packaging). Although located in international logistics zones, simple processing DCs only have the functions of a simple process for semi-products and finished products. Non-bonded DCs perform the same functions as deep processing DCs, but they are located in tax areas. Based on the function of DCs mentioned above, deep processing DCs and non-bonded DCs receive modular components from vendors. DCs may also receive semi-products or finished products from manufacturing centers.

Furthermore, semi-products or finished products can be transferred between all kinds of DCs.

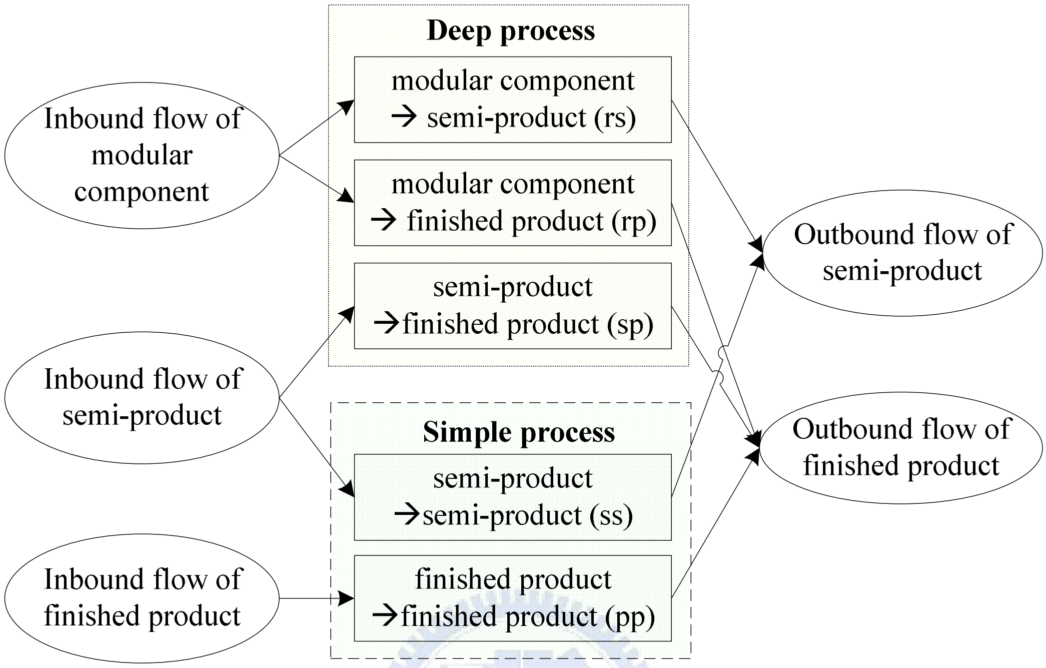

Figure 3-2 Deep process and simple process functions

This analysis assumes venders in a typical supply chain to be located below the top upstream suppliers. They receive and then process raw materials from upstream suppliers in order to manufacture modular components, which are then sent to manufacturing centers, deep processing DCs or non-bonded DCs.

Brand companies will request global manufacturers to distribute finished products to assigned locations around the world. Assigned locations could be DCs or warehouses owned by these brand companies. Figure 3-3 shows the flow of goods.

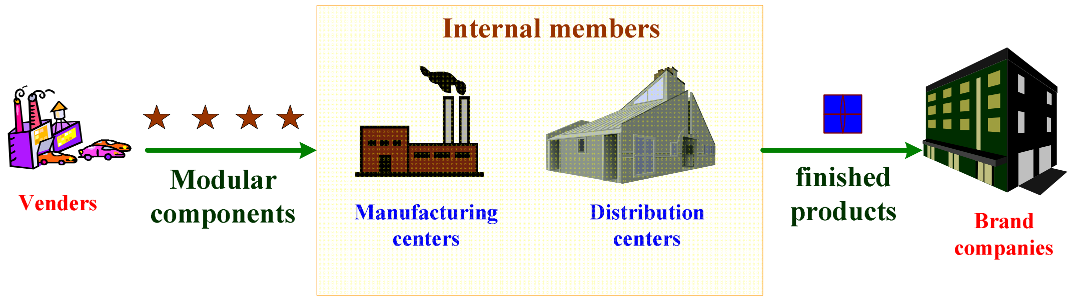

Figure 3-3 Flow of goods

Once both processing DCs and international logistics zones are incorporated in the emerging global production-distribution network, global manufacturers have difficulty in determining the optimal tax savings route and manufacturing procedures for each order. Moreover, to identify the best tax savings route and manufacturing procedures, an after-tax model should allow for goods free transfer among processing DCs. Restated, a finished product may be processed via simple or deep processing, or both, in various DCs.

3.3 Transactions

Since many brand companies often contract with global manufacturers for delivered duty paid (DDP) transactions, transactions in our model are based on the DDP value of the shipment. Herein, DDP means that the seller bears the risks and costs, including taxes, duties and other charges of transporting the goods until they have been delivered.

CHAPTER 4 TAX SAVINGS APPROACHES

According to in-depth interviews with global manufacturers, the three key tax factors contributing to operating income are: import duties, value added tax and corporate tax. Furthermore, considering the characteristics of international logistics zones, the conditions for evaluation of import duties, value added tax and corporate tax are more complex in the emerging network than in a typical network. The tax savings approaches for these three taxes are outlined below.

4.1 Import Duty

Import duties are tariffs paid to the relative government as goods pass into tax areas. Issues of import duties can be divided into the following three dimensions.

1. Charge condition

As situation depicted in Figure 4-1, the charge condition of import duty is that for the same country original flows are in international logistics zones and destination flows are in tax areas, while for different countries destination flows are in tax areas.

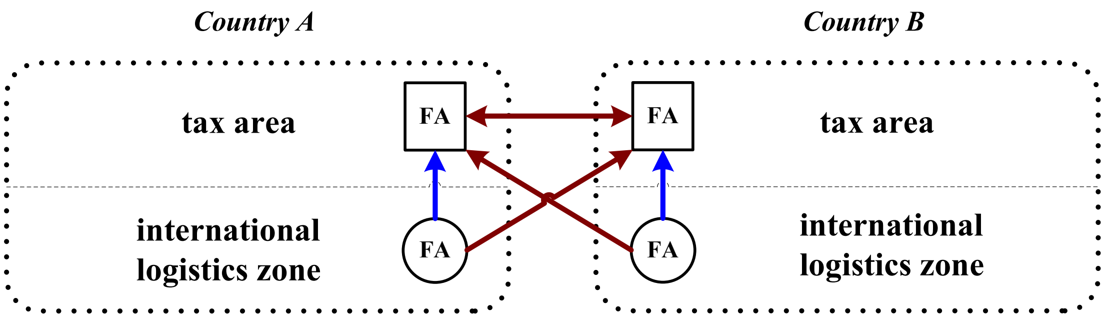

Figure 4-1 Charge condition of import duty

2. Import from low duty rate country

Since duty rates may differ between countries for the same goods, enterprises can reduce costs by importing goods from countries with lower duties. As Figure 4-2 shows, import duties from country *B* ($80=$800*10%) are lower than from country *A* ($400=$800*50%) for the same goods ($800). Consequently, assuming all other conditions are equal, the enterprise can save import duties by importing via the low duty country.

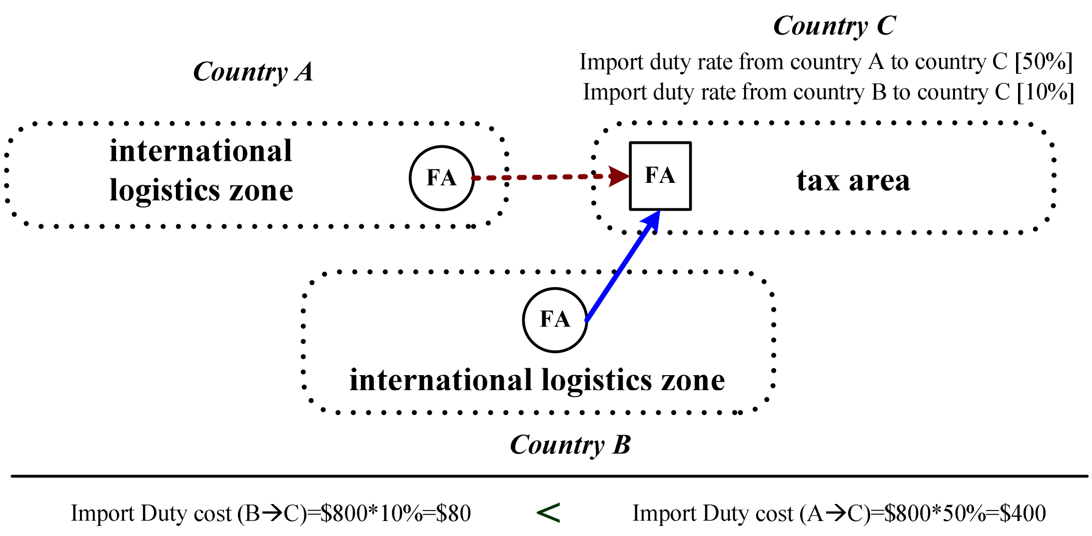

Figure 4-2 Import from low duty country

3. Import duty and product forms

Duty rates change with respect to product form, and manufacturers must then determine the most advantageous trade-off between import duty and processing cost. For instance, assuming country B requires the finished products in Figure 4-3, manufacturers must decide whether to (1) convert raw materials into finished products in country A and then import the finished products to country B or (2) import raw materials from country A and then convert the raw materials into finished products in country B.

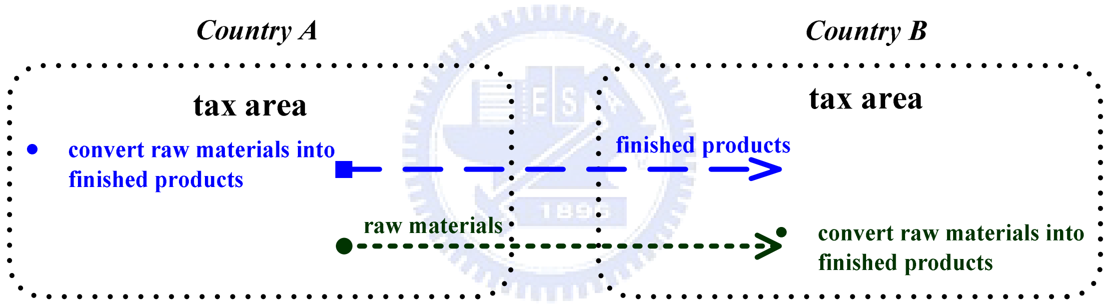

Figure 4-3 Import duty and product forms

4.2 Value Added Tax

Assessment of value added tax (VAT) is based on the incremental increase in the value of goods from raw materials to finished products. For each transaction, VAT is levied on the increased value of a product after input from previous chain members. Value added tax is generally formulated as follows:

$$VATcost = p^s \times q^s \times VAT - p^i \times q^i \times VAT + p^o \times q^o \times (VAT - DRT) \qquad (1)$$

where $VATcost$ implies the cost of VAT; p^s, p^i, p^o represent the prices associated with sale, input and export, respectively; q^s, q^i, q^o denote the quantities associated with sale, input and export, respectively; VAT indicates VAT rate (%) on the value of goods; DRT signifies VAT drawback rate (%) on the value of goods.

The first term in Eq. (1) represents sales VAT, and the second term denotes input VAT. Sales VAT can be offset by input VAT. Further, the third term is regarded as export VAT which refers to the VAT imposed on certain exported goods in some countries, e.g. China. Thus, governments adopt strategies for regulating the VAT drawback rate for exports. For example, a country may increase the VAT drawback rate to promote the exporting of certain goods (e.g. mechanical and electrical products) whereas a country may decrease the VAT drawback rate for goods that were restricted to exporting (e.g. natural resources).

As Figure 4-4 illustrates, according to a DC in tax areas or in international logistics zones, the charge condition of sales VAT is that destination flows are in tax areas for the same country, while the charge condition of input VAT is that neither original nor destination flows are in international logistics zones. Further, the charge condition of export VAT is that, in the same country, original flows are in tax areas, and destination flows are in international logistics zones; for different countries, both original and destination flows are not in international logistics zones. Consequently, international logistic zones enable enterprises to avoid government regulation strategies of export VAT.

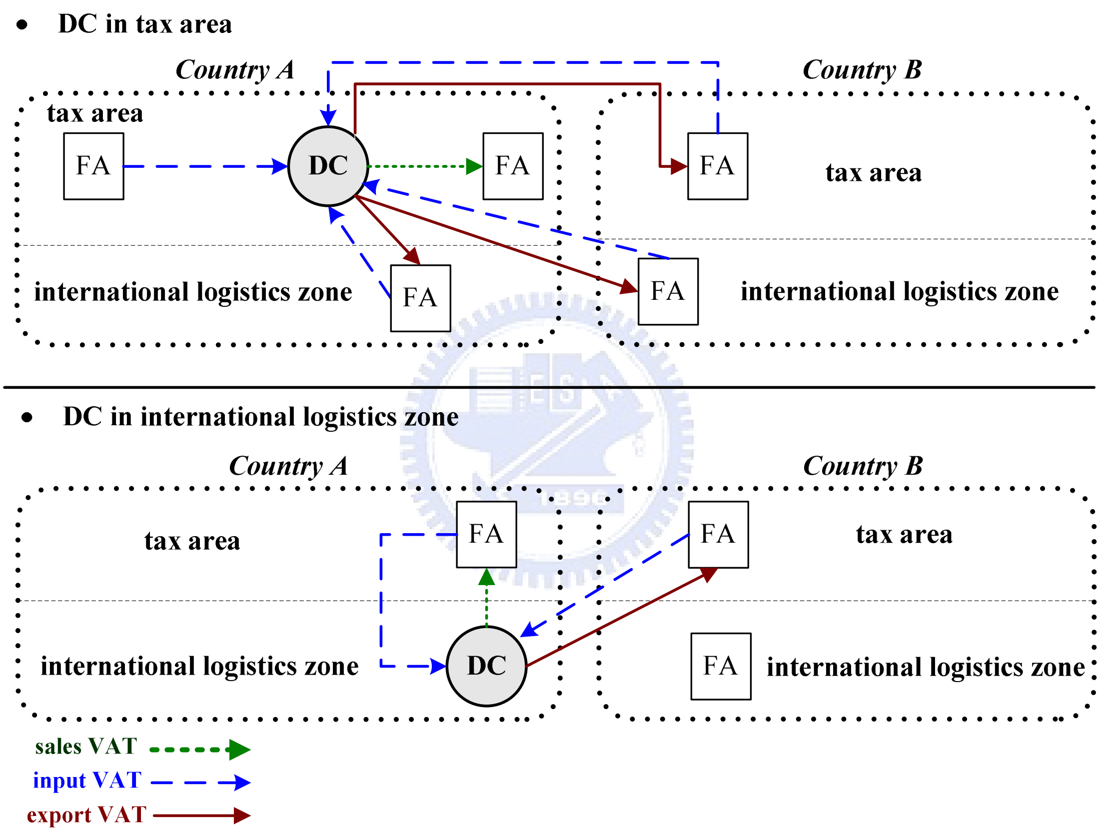

Figure 4-4 Charge condition of VAT

4.3 Corporate Tax

Corporate tax is the tax paid by enterprises on the profit they earn. For tax savings, goods completely manufactured in international logistics zones are exempt from corporate tax. Nevertheless, manufacturers must identify the most advantageous trade-off between corporate tax and other costs (e.g., import duties).

Products can be manufactured primarily in international logistics zones in order to save corporate tax. As Figure 4-5 illustrates, an example of the tax-saving approach concerning corporate tax for the requirement of finished products in country C. Goods are transformed from raw materials into semi-products in country A, then the semi-products are shipped from country A to country B for further transformation from semi-products into finished products. Finally, the finished products are shipped from country B to country C. Accordingly, the tax-saving route (A➔B➔C) saves $750 over that of direct shipment (A➔C).

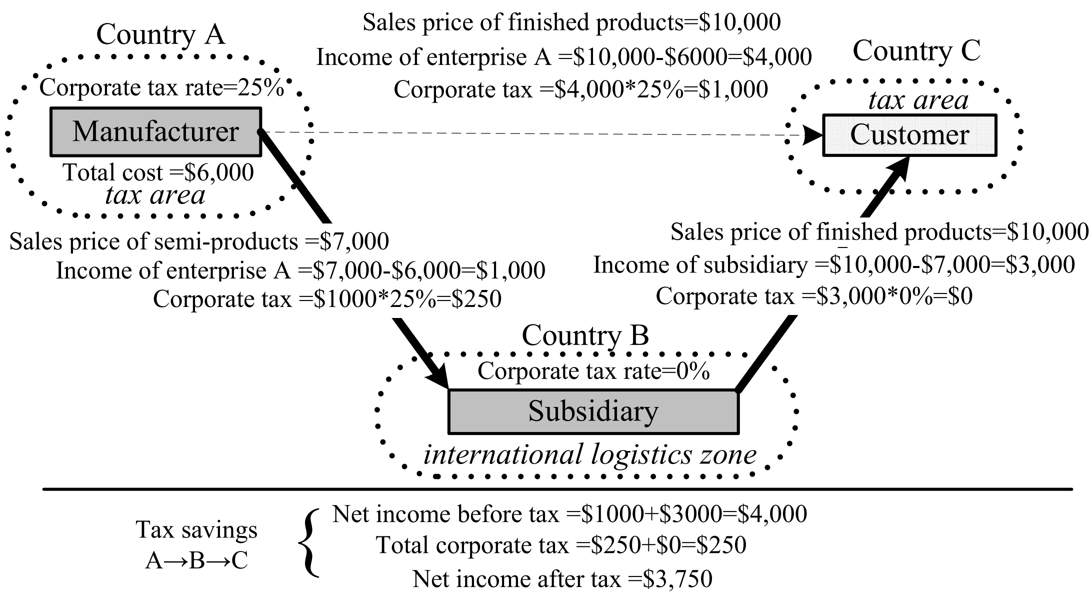

Figure 4-5 Routes for minimizing corporate tax

Furthermore, two possibilities exist with regard to paying corporate tax: (1) paying corporate tax to multiple governments in the various jurisdictions where the enterprise operates; (2) paying corporate tax to one government based on headquarter location. To facilitate model formulation, this study focuses on situation (1).

CHAPTER 5 MODELING

Given the problem statement, a tax savings model is formulated to derive after-tax solutions that maximize profit in the emerging global production-distribution network. The proposed model is based on models developed by Vidal and Goetschalckx (1998), Vidal and Goetschalckx (2000), Vidal and Goetschalckx (2001), Fandel and Stammen (2004) and Vila *et al*. (2006). Nevertheless, once the after-tax model considers the emerging global production-distribution network, determining the optimal tax savings route and manufacturing procedure for each order is difficult. Furthermore, three principal tax factors—import duty, value added tax and corporate tax—are considered simultaneously in the proposed model. Before formulating the proposed model, basic notations and definitions are presented. This chapter is divided into three sections: (1) notations and definitions, (2) objective function and (3) constraints.

5.1 Notations and Definitions

All the notations and definitions for sets, decision variables and parameters are summarized as follows.

1. Sets

FA Set of internal and external supply chain members. Herein, FA^V : set of vendors (abbreviated as V); FA^M : set of manufacturing centers (abbreviated as M); FA^{Ds} : set of simple processing DCs (abbreviated as Ds ; FA^{Dd} : set of deep processing DCs (abbreviated as Dd); FA^{Dn} : set of non-bonded DC (abbreviated as Dn); FA^B : set of brand companies (abbreviated as B); FA^I : set of all internal supply chain members (abbreviated as I); FA^{DC} : set of all DCs, including deep processing DCs, simple processing DCs and non-bonded DCs (abbreviated as DC); FA_C : set of chain members in international logistics zones (abbreviated as C); FA_T : set of chain members in tax areas (abbreviated as T).

G Set of types of goods. Herein, G^r : set of modular components (abbreviated as r); G^s : set of semi-products (abbreviated as s); G^p : set of finished products (abbreviated as p).

N Set of countries.

SN Set of simple and deep process product lines. Herein,

SN^{rs}: set of product lines involving transformation of modular components r into semi-products s (abbreviated as rs); SN^{rp}: set of product lines involving transformation of modular components r into finished products p (abbreviated as rp); SN^{sp}: set of product lines involving transformation of semi-products s into finished products p (abbreviated as sp); SN^{ss}: set of product lines involving simple processing of semi-products s (abbreviated as ss); SN^{pp}: set of product lines involving simple processing of finished products p (abbreviated as pp); SN_I: set of product lines of inbound flow (abbreviated as I); SN_O: set of product lines of outbound flow (abbreviated as O); SN^R: set of product lines of sum of corresponding modular components (abbreviated as R); SN^S: set of product lines of sum of corresponding semi-products (abbreviated as S); SN^P: set of product lines of sum of corresponding finished products (abbreviated as P).

Ω Set of transportation modes. Here, $\Omega(\theta^x, \lambda^y)$ is the set of available transportation modes between a given chain member θ in the country $x \in N$ and another given chain member λ in the country $y \in N$.

2. Decision variables

$gotr_{\theta^x \alpha\beta}$ Binary decision variable indicates whether goods transformation occurs at a given chain member θ in country $x \in N$ when transferring ancestor goods α into descendant goods β.

$gt_{\theta^x \alpha f}$ Binary decision variable indicates whether goods α is in progress in a product line f at a given chain member θ in country $x \in N$.

oi_{θ^x} Operating income of a given chain member θ in country $x \in N$ for the period of analysis (dollar/unit of time).

$ord_{\theta^x \alpha}$ Number of nodes visited on the transfer path from the origin up to node θ^x for goods α (i.e., the visit number of the θ^x th node).

$qu_{\theta^x \lambda^y m\alpha}$ Binary decision variable representing whether goods $\alpha \in G$ is shipped from a given chain member θ in country $x \in N$

to another given chain member λ in country $y \in N$, using transportation mode $m \in \Omega(\theta^x, \lambda^y)$.

3. Parameters

BR_{λ^y} Required finished products for a given chain member λ in country $y \in N$ (units of *p*/unit of time).

$BOM_{\alpha\beta}$ Units of ancestor goods $\alpha \in G$ required to make one unit of descendant goods $B \in G$ (α-units/ β-unit).

BN A big number.

CSF Cycle stock factor (%).

COT_{θ^x} Corporate tax rate (%) of country $x \in N$ of a supply chain member θ.

$CPRICE_\alpha$ International contract price of goods $\alpha \in G$ (dollar/unit of goods α)

$DRT_{\theta^x\alpha}$ Value added tax drawback rate (%) on the value of goods $\alpha \in G$ of country $x \in N$ of supply chain member θ.

$DUTY_{\theta^x\lambda^y\alpha}$ Import duty rate (%) on the value of goods $\alpha \in G$ shipped from a given chain member θ in country $x \in N$ to another given chain member λ in country $y \in N$.

E_{θ^x} — Exchange rate of country $x \in N$ of supply chain member θ (monetary units of the respective country/dollar).

FIX_{θ^x} — Fixed cost associated with a given chain member θ in country $x \in N$ (monetary units of country of member θ per unit of time).

$FS_{\theta^x \lambda^y m}$ — Frequency of goods shipments from a given chain member θ in country $x \in N$ to another given chain member λ in country $y \in N$, using transportation mode $m \in \Omega(\theta^x, \lambda^y)$ (units of time).

H — Holding cost (\$/(\$. unit of time)).

$IV_{\theta^x \alpha}$ — Inventory value of goods $\alpha \in G$, given in monetary units of a given chain member θ in country $x \in N$ per unit of goods α.

$NODE$ — Number of DC nodes.

$PROC_{\lambda^y \theta^x \alpha}$ — Procurement cost (including total cost and taxes) of goods $\alpha \in G$ shipped from a given chain member λ in country $y \in N$ to another given chain member θ in country $x \in N$ (monetary units of country of member λ/unit of goods α).

PPA_{θ^x} Simple processing capacity of finished products in a given chain member θ in country $x \in N$ (finished product units/unit of time).

PPC_{θ^x} Simple processing cost of finished products in a given chain member θ in country $x \in N$ (monetary units of country of member θ/unit of finished product).

RSA_{θ^x} Capacity to transform goods associated with a given chain member θ in country $x \in N$ for transferring modular components into semi-products (semi-product units/unit of time).

RSC_{θ^x} Cost of transforming goods associated with a given chain member θ in country $x \in N$ for transferring modular components into semi-products (monetary units of country of member θ/ unit of semi-products).

RPA_{θ^x} Capacity to transform goods associated with a given chain member θ in country $x \in N$ for transferring modular components into finished products (finished product units/unit of time).

RPC_{θ^x} Cost of transforming goods associated with a given chain member θ in country $x \in N$ for transferring modular components into finished products in country $x \in N$ (monetary units of country of member θ/ unit of finished products).

SPA_{θ^x} Capacity to transform goods associated with a given chain member θ in country $x \in N$ for transferring semi-products into finished products (finished product units/unit of time).

SPC_{θ^x} Cost of transforming goods associated with a given chain member θ in country $x \in N$ for transferring semi-products into finished products (monetary units of country of member θ/ unit of finished products).

SSA_{θ^x} Simple processing capacity of semi-product in a given chain member θ in country $x \in N$ (semi-product units/unit of time).

SSC_{θ^x} Simple processing cost of semi-product in a given chain member θ in country $x \in N$ (monetary units of country of member θ/unit of s).

$SSF_{\theta^x \alpha}$ Safety stock factor of goods $\alpha \in G$ at a given chain member θ in country $x \in N$.

$TP_{\theta^x \alpha}$ Transfer price of goods $\alpha \in G$ shipped from a given chain member θ in country $x \in N$ (monetary units of country of member θ/unit of goods α).

$TRC_{\theta^x \lambda^y m}$ Transportation cost per weight unit of goods shipped from a given chain member θ in country $x \in N$ to another given chain member λ in country $y \in N$, using transportation mode $m \in \Omega(\theta^x, \lambda^y)$ (monetary units of country of member θ/weight unit).

$TT_{\theta^x \lambda^y m}$ Average transportation time from a given chain member θ in country $x \in N$ to another given chain member λ in country $y \in N$, using transportation mode $m \in \Omega(\theta^x, \lambda^y)$ (units of time).

VC_{θ^x} Capacity of a given chain member θ in country $x \in N$ for supplying modular components (modular component units/unit of time).

$VAT_{\theta^x \alpha}$ Value added tax rate (%) on the value of goods $\alpha \in G$ of country $x \in N$ of supply chain member θ.

W_α Weight of a unit of goods $\alpha \in G$ (weight units/unit of goods).

5.2 The Objective Function

The objective function maximizes global after-tax profit in dollars for the period of analysis. The after-tax profit of internal supply chain members involved in the objective function are expressed in Eq. (2). The operating income variables oi_{θ^x} are free variables since operating income may be positive, zero or negative. Accordingly, each variable is treated as the difference between a plus non-negative variable (operating profit) $oi^+_{\theta^x} = oi_{\theta^x}$ and a minus non-negative variable (operating loss) $oi^-_{\theta^x} = -oi_{\theta^x}$ (Vidal and Goetschalckx, 1998; Vidal and Goetschalckx, 2001; Fandel and Stammen, 2004; Vila *et al.*, 2006).

$$Maximize \quad \sum_{\theta^x \in FA^I} \left[(1 - COT_{\theta^x}) oi^+_{\theta^x} - oi^-_{\theta^x} \right] \tag{2}$$

Each operating income variable is measured by subtracting the corresponding aggregate costs $cost_{\theta^x}$ $(= \sum_{k=1}^{24} z^k_{\theta^x})$ from the respective aggregate revenues $revenue_{\theta^x}$ $(= \pi^1_{\theta^x} + \pi^2_{\theta^x})$, as Eq. (3) demonstrates.

$$oi^+_{\theta^x} - oi^-_{\theta^x} = revenue_{\theta^x} - cost_{\theta^x}, \quad \forall \theta^x \in FA^I \tag{3}$$

Trading with internal supply chain members and brand companies produces the corresponding aggregate revenue, as expressed in Eqs. (4) and (5), respectively. Here, transfer price $TP_{\theta^x \lambda^y \alpha}$ is given to avoid costly auditing and litigation. An effective method for obtaining market-driven transfer prices was proposed in Lakhal *et al*. (2005).

$$\pi^1_{\theta^x} = \sum_{\lambda^y (\theta^x \neq \lambda^y) \in FA^I} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^{sp}} \frac{1}{E_{\theta^x}} \times TP_{\theta^x \alpha} \times qu_{\theta^x \lambda^y m \alpha}, \quad \forall \theta^x \in FA^I \tag{4}$$

$$\pi^2_{\theta^x} = \sum_{\lambda^y \in FA^B} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^p} CPRICE_{\alpha} \times qu_{\theta^x \lambda^y m \alpha}, \quad \forall \theta^x \in FA^{DC} \tag{5}$$

The aggregate cost is composed of 24 items. They are the corresponding aggregate costs in terms of transforming modular components into semi-products (Eq. (6)), transforming modular components into finished products (Eq. (7)), transforming semi-products into finished products (Eq. (8)), simple process of semi-products (Eq. (9)), simple process of finished products (Eq. (10)), transportation cost of trading with internal supply chain members (Eq. (11)), transportation cost of trading with brand companies (Eq. (12)), inventory cost of trading with internal supply chain members (Eq. (13)), inventory cost of trading with brand companies (Eq. (14)), procurement cost of raw materials (Eq. (15)), procurement cost of semi-products or finished products (Eq. (16)), fixed cost (Eq. (17)), sales VAT trading with internal members (Eq. (18)), sales VAT trading with brand companies (Eq. (19)), input VAT trading with vendors (Eq. (20)), input VAT trading with internal members (Eq. (21)), export VAT trading with internal members in the same country (Eq. (22)), export VAT trading with brand companies in the same country (Eq. (23)), export VAT trading with internal members in different countries (Eq. (24)), export VAT trading with brand companies in different countries (Eq. (25)), import duty trading with internal members in the same country (Eq. (26)), import duty trading with brand companies in the same country (Eq. (27)), import duty trading with internal members in different countries (Eq. (28)), import duty trading with brand companies in different countries (Eq. (29)). Note that Eqs. (20) and (21) are minus items as mentioned in Chapter four. Furthermore, the term $\left[TT_{\theta^x \lambda^y m} + CSF \times FS_{\theta^x \lambda^y m} + SSF_{\theta^x \alpha}\sqrt{TT_{\theta^x \lambda^y m}}\right]$ in Eqs. (13) and (14) is the total time required to calculate inventory costs (Vidal and Goetschalckx, 2000). Herein, the first term is the time required to measure the pipeline inventory; the second term is the time required to measure the cycle inventory; the third term is the time required to measure the safety stock (Vidal and Goetschalckx, 2000). The gamma distribution was adopted in the safety stock for modeling stochastic lead times and inventory problems (Vidal and Goetschalckx, 2000).

$$z_{\theta^x}^{1} = \sum_{\alpha\in G^s} \sum_{f\in SN_O^{rs}} \frac{1}{E_{\theta^x}} \times RSC_{\theta^x} \times gt_{\theta^x \alpha f}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\} \tag{6}$$

$$z_{\theta^x}^{2} = \sum_{\alpha\in G^p} \sum_{f\in SN_O^{rp}} \frac{1}{E_{\theta^x}} \times RPC_{\theta^x} \times gt_{\theta^x \alpha f}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\} \tag{7}$$

$$z_{\theta^x}^{3} = \sum_{\alpha\in G^p} \sum_{f\in SN_O^{sp}} \frac{1}{E_{\theta^x}} \times SPC_{\theta^x} \times gt_{\theta^x \alpha f}, \quad \forall \theta^x \in \left\{FA^{Dd}, FA^{Dn}\right\} \tag{8}$$

$$z_{\theta^x}^{4} = \sum_{\alpha\in G^s} \sum_{f\in SN_O^{ss}} \frac{1}{E_{\theta^x}} \times SSC_{\theta^x} \times gt_{\theta^x \alpha f}, \quad \forall \theta^x \in FA^{DC} \tag{9}$$

$$z_{\theta^x}^{5} = \sum_{\alpha\in G^p} \sum_{f\in SN_O^{pp}} \frac{1}{E_{\theta^x}} \times PPC_{\theta^x} \times gt_{\theta^x \alpha f}, \quad \forall \theta^x \in FA^{DC} \tag{10}$$

$$z_{\theta^x}^{6} = \sum_{\lambda^y(\theta^x\neq\lambda^y)\in FA^I} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^{SP}} \frac{1}{E_{\theta^x}} \times TRC_{\theta^x\lambda^y m} \times W_\alpha \times qu_{\theta^x\lambda^y m\alpha}, \quad \forall \theta^x \in FA^I \tag{11}$$

$$z_{\theta^x}^{7} = \sum_{\lambda^y\in FA^B} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^P} \frac{1}{E_{\theta^x}} \times TRC_{\theta^x\lambda^y m} \times W_\alpha \times qu_{\theta^x\lambda^y m\alpha}, \quad \forall \theta^x \in FA^{DC} \tag{12}$$

$$z_{\theta^x}^{8} = \sum_{\lambda^y(\theta^x\neq\lambda^y)\in FA^I} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^{SP}} \frac{IV_{\theta^x\alpha}\times H}{E_{\theta^x}} \left[TT_{\theta^x\lambda^y m} + CSF \times FS_{\theta^x\lambda^y m} + SSF_{\theta^x\alpha}\sqrt{TT_{\theta^x\lambda^y m}}\right] qu_{\theta^x\lambda^y m\alpha}, \quad \forall \theta^x \in FA^I \tag{13}$$

$$z_{\theta^x}^{9} = \sum_{\lambda^y\in FA^B} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^P} \frac{IV_{\theta^x\alpha}\times H}{E_{\theta^x}} \left[TT_{\theta^x\lambda^y m} + CSF \times FS_{\theta^x\lambda^y m} + SSF_{\theta^x\alpha}\sqrt{TT_{\theta^x\lambda^y m}}\right] qu_{\theta^x\lambda^y m\alpha}, \quad \forall \theta^x \in FA^{DC} \tag{14}$$

$$z_{\theta^x}^{10} = \sum_{\lambda^y\in FA^V} \sum_{m\in\Omega(\lambda^y,\theta^x)} \sum_{\alpha\in G^r} \frac{1}{E_{\lambda^y}} \times PROC_{\lambda^y\theta^x\alpha} \times qu_{\lambda^y\theta^x m\alpha}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\} \tag{15}$$

$$z_{\theta^x}^{11} = \sum_{\lambda^y(\theta^x\neq\lambda^y)\in FA^I} \sum_{m\in\Omega(\lambda^y,\theta^x)} \sum_{\alpha\in G^{sp}} \frac{1}{E_{\lambda^y}} \times TP_{\lambda^y\alpha} \times qu_{\lambda^y\theta^x m\alpha}, \quad \forall \theta^x \in FA^I \tag{16}$$

$$z_{\theta^x}^{12} = \frac{1}{E_{\theta^x}} \times FIX_{\theta^x}, \quad \forall \theta^x \in FA^I \tag{17}$$

$$z_{\theta^x}^{13} = \sum_{\lambda^y(\theta^x\neq\lambda^y \& x=y)\in FA_T^I} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^{sp}} \frac{1}{E_{\theta^x}} \times TP_{\theta^x\alpha} \times qu_{\theta^x\lambda^y m\alpha} \times VAT_{\theta^x\alpha}, \quad \forall \theta^x \in FA^I \tag{18}$$

$$z_{\theta^x}^{14} = \sum_{\lambda^y(x=y)\in FA_T^B} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^P} CPRICE_\alpha \times qu_{\theta^x\lambda^y m\alpha} \times VAT_{\theta^x\alpha}, \quad \forall \theta^x \in FA^{DC} \tag{19}$$

$$z_{\theta^x}^{15} = \sum_{\lambda^y\in FA^V,\theta^x \& \lambda^y\notin FA_C} \sum_{m\in\Omega(\lambda^y,\theta^x)} \sum_{\alpha\in G^r} \frac{1}{E_{\lambda^y}} \times PROC_{\lambda^y\theta^x\alpha} \times qu_{\lambda^y\theta^x m\alpha} \times VAT_{\lambda^y\alpha}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\} \tag{20}$$

$$z_{\theta^x}^{16} = \sum_{\lambda^y(\theta^x\neq\lambda^y)\in FA^I,\theta^x \& \lambda^y\notin FA_C} \sum_{m\in\Omega(\lambda^y,\theta^x)} \sum_{\alpha\in G^{sp}} \frac{1}{E_{\lambda^y}} \times TP_{\lambda^y\alpha} \times qu_{\lambda^y\theta^x m\alpha} \times VAT_{\lambda^y\alpha}, \quad \forall \theta^x \in FA^I \tag{21}$$

$$z_{\theta^x}^{17} = \sum_{\lambda^y(\theta^x\neq\lambda^y \& x=y)\in FA_C^I} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^{sp}} \frac{1}{E_{\theta^x}} \times TP_{\theta^x\alpha} \times qu_{\theta^x\lambda^y m\alpha} \times (VAT_{\theta^x\alpha} - DRT_{\theta^x\alpha}), \quad \forall \theta^x \in FA_T^I \tag{22}$$

$$z_{\theta^x}^{18} = \sum_{\lambda^y(\theta^x\neq\lambda^y \& x=y)\in FA_C^B} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^p} CPRICE_\alpha \times qu_{\theta^x\lambda^y m\alpha} \times (VAT_{\theta^x\alpha} - DRT_{\theta^x\alpha}), \quad \forall \theta^x \in FA_T^{DC} \tag{23}$$

$$z_{\theta^x}^{19} = \sum_{\lambda^y(\theta^x\neq\lambda^y \& x\neq y)\in FA^I,\theta^x \& \lambda^y\notin FA_C} \sum_{m\in\Omega(\theta^x,\lambda^y)} \sum_{\alpha\in G^{sp}} \frac{1}{E_{\theta^x}} \times TP_{\theta^x\alpha} \times qu_{\theta^x\lambda^y m\alpha} \times (VAT_{\theta^x\alpha} - DRT_{\theta^x\alpha}), \quad \forall \theta^x \in FA^I \tag{24}$$

$$z_{\theta^x}^{20} = \sum_{\lambda^y(\theta^x \neq \lambda^y \& x \neq y) \in FA^B, \theta^x \& \lambda^y \notin FA_C} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^p} CPRICE_\alpha \times qu_{\theta^x \lambda^y m\alpha} \times (VAT_{\theta^x \alpha} - DRT_{\theta^x \alpha}), \quad \forall \theta^x \in FA^{DC} \tag{25}$$

$$z_{\theta^x}^{21} = \sum_{\lambda^y(\theta^x \neq \lambda^y \& x = y) \in FA_T^I} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^{sp}} \frac{1}{E_{\theta^x}} \times (TP_{\theta^x \alpha} + TRC_{\theta^x \lambda^y m} \times W_\alpha) \times qu_{\theta^x \lambda^y m\alpha} \times DUTY_{\theta^x \lambda^y \alpha}, \quad \forall \theta^x \in FA_C^I \tag{26}$$

$$z_{\theta^x}^{22} = \sum_{\lambda^y(\theta^x \neq \lambda^y \& x = y) \in FA_T^B} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^p} (CPRICE_\alpha + \frac{1}{E_{\theta^x}} \times TRC_{\theta^x \lambda^y m} \times W_\alpha) \times qu_{\theta^x \lambda^y m\alpha} \times DUTY_{\theta^x \lambda^y \alpha}, \quad \forall \theta^x \in FA_C^{DC} \tag{27}$$

$$z_{\theta^x}^{23} = \sum_{\lambda^y(\theta^x \neq \lambda^y \& x \neq y) \in FA_T^I} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^{SP}} \frac{1}{E_{\theta^x}} \times (TP_{\theta^x \alpha} + TRC_{\theta^x \lambda^y m} \times W_\alpha) \times qu_{\theta^x \lambda^y m\alpha} \times DUTY_{\theta^x \lambda^y \alpha}, \quad \forall \theta^x \in FA^I \tag{28}$$

$$z_{\theta^x}^{24} = \sum_{\lambda^y(\theta^x \neq \lambda^y \& x \neq y) \in FA_T^B} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^P} (CPRICE_\alpha + \frac{1}{E_{\theta^x}} \times TRC_{\theta^x \lambda^y m} \times W_\alpha) \times qu_{\theta^x \lambda^y m\alpha} \times DUTY_{\theta^x \lambda^y \alpha}, \quad \forall \theta^x \in FA^{DC} \tag{29}$$

5.3 Constraints

Given that corresponding logistics conditions are limited by operating requirements, eleven groups of constraints are the following: flow conservation of deep and simple process, inbound flow conservation, outbound flow conservation, identifying goods transformations, maximum goods transformation, assignment of goods, brand company requirements, capacity of chain members, subtour breaking constraints, binary constraints, and non-negative constraints. These constraints are further elaborated below.

1. Flow conservation of deep and simple process

As Figure 3-2 shows, deep process, including transforming modular components into semi-products, transforming modular components into finished products and transforming semi-products into finished products, are expressed as Eqs. (30), (31) and (32), respectively.

$$\sum_{\alpha\in G^r}\sum_{f\in SN_I^{rs}} gt_{\theta^x\alpha f} = \sum_{\beta\in G^s}\sum_{f\in SN_O^{rs}} gt_{\theta^x\beta f}\times BOM_{\alpha\beta},\quad \forall\theta^x\in\left\{FA^M,FA^{Dd},FA^{Dn}\right\} \tag{30}$$

$$\sum_{\alpha\in G^r}\sum_{f\in SN_I^{rp}} gt_{\theta^x\alpha f} = \sum_{\beta\in G^p}\sum_{f\in SN_O^{rp}} gt_{\theta^x\beta f}\times BOM_{\alpha\beta},\quad \forall\theta^x\in\left\{FA^M,FA^{Dd},FA^{Dn}\right\} \tag{31}$$

$$\sum_{\alpha\in G^s}\sum_{f\in SN_I^{sp}} gt_{\theta^x\alpha f} = \sum_{\beta\in G^p}\sum_{f\in SN_O^{sp}} gt_{\theta^x\beta f}\times BOM_{\alpha\beta},\quad \forall\theta^x\in\left\{FA^{Dd},FA^{Dn}\right\} \tag{32}$$

Simple process involving simple processing of semi-products and finished products are expressed as Eqs. (33) and (34), respectively.

$$\sum_{f\in SN_I^{ss}} gt_{\theta^x\alpha f} = \sum_{f\in SN_O^{ss}} gt_{\theta^x\alpha f},\quad \forall\theta^x\in\left\{FA^{Dd},FA^{Ds},FA^{Dn}\right\},\forall\alpha\in G^s \tag{33}$$

$$\sum_{f\in SN_I^{pp}} gt_{\theta^x\alpha f} = \sum_{f\in SN_O^{pp}} gt_{\theta^x\alpha f},\quad \forall\theta^x\in\left\{FA^{Dd},FA^{Ds},FA^{Dn}\right\},\forall\alpha\in G^p \tag{34}$$

2. Inbound flow conservation

Figure 3-2 shows three inbound flows: modular components, semi-products, and finished products. Consequently, the corresponding inbound flow constraints are expressed as Eqs. (35), (36) and (37), respectively.

$$\sum_{\theta^x\in FA^V}\sum_{m\in\Omega(\theta^x,\lambda^y)} qu_{\theta^x\lambda^y m\alpha} = \sum_{f\in SN_I^R} gt_{\lambda^y\alpha f},\quad \forall\lambda^y\in\left\{FA^M,FA^{Dd},FA^{Dn}\right\},\alpha\in G^r \tag{35}$$

$$\sum_{\theta^x(\theta^x\neq\lambda^y)\in FA^I}\sum_{m\in\Omega(\theta^x,\lambda^y)} qu_{\theta^x\lambda^y m\alpha} = \sum_{f\in SN_I^S} gt_{\lambda^y\alpha f},\quad \forall\lambda^y\in\left\{FA^{DC}\right\},\alpha\in G^s \tag{36}$$

$$\sum_{\theta^x(\theta^x\neq\lambda^y)\in FA^I}\sum_{m\in\Omega(\theta^x,\lambda^y)} qu_{\theta^x\lambda^y m\alpha} = \sum_{f\in SN_I^P} gt_{\lambda^y\alpha f},\quad \forall\lambda^y\in\left\{FA^{DC}\right\},\alpha\in G^p \tag{37}$$

3. Outbound flow conservation

As Figure 3-2 shows, two outbound flows are semi-products and finished products. Regarding finished products, manufacturing centers only can convey finished products to DCs, while DCs convey finished products to brand companies or other DCs. Consequently, the corresponding outbound flow constraints are expressed as Eqs. (38), (39) and (40), respectively.

$$\sum_{f \in SN_O^S} gt_{\theta^x \alpha f} = \sum_{\lambda^y (\theta^x \neq \lambda^y) \in FA^{DC}} \sum_{m \in \Omega(\theta^x, \lambda^y)} qu_{\theta^x \lambda^y m \alpha}, \quad \forall \theta^x \in FA^I, \alpha \in G^s \tag{38}$$

$$\sum_{f \in SN_O^P} gt_{\theta^x \alpha f} = \sum_{\lambda^y \in FA^{DC}} \sum_{m \in \Omega(\theta^x, \lambda^y)} qu_{\theta^x \lambda^y m \alpha}, \quad \forall \theta^x \in FA^M, \alpha \in G^p \tag{39}$$

$$\sum_{f \in SN_O^P} gt_{\theta^x \alpha f} = \sum_{\lambda^y (\theta^x \neq \lambda^y) \in \left\{FA^{DC}, FA^B\right\}} \sum_{m \in \Omega(\theta^x, \lambda^y)} qu_{\theta^x \lambda^y m \alpha}, \quad \forall \theta^x \in FA^{DC}, \alpha \in G^p \tag{40}$$

4. Identifying goods transformations

For the sake of rational goods transformations and assignments, the expression $gotr_{\theta^x \alpha\beta}$ represents good transformations, including transformations from modular components into semi-products, from modular components into finished products and from semi-products into finished products. Accordingly, the corresponding constraints on goods transformations are expressed in Eqs. (41), (42) and (43), respectively.

$$\begin{cases} \sum_{\alpha \in G^r} gotr_{\theta^x \alpha\beta} \leq \sum_{f \in SN_O^{rs}} gt_{\theta^x \beta f} * BN \\ \sum_{f \in SN_O^{rs}} gt_{\theta^x \beta f} \leq \sum_{\alpha \in G^r} gotr_{\theta^x \alpha\beta} * BN \end{cases}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\}, \beta \in G^s \tag{41}$$

$$\begin{cases} \sum_{\alpha \in G^r} gotr_{\theta^x \alpha\beta} \leq \sum_{f \in SN_O^{rp}} gt_{\theta^x \beta f} * BN \\ \sum_{f \in SN_O^{rp}} gt_{\theta^x \beta f} \leq \sum_{\alpha \in G^r} gotr_{\theta^x \alpha\beta} * BN \end{cases}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\}, \beta \in G^p \tag{42}$$

$$\begin{cases} \sum_{\alpha \in G^s} gotr_{\theta^x \alpha\beta} \leq \sum_{f \in SN_O^{sp}} gt_{\theta^x \beta f} * BN \\ \sum_{f \in SN_O^{sp}} gt_{\theta^x \beta f} \leq \sum_{\alpha \in G^s} gotr_{\theta^x \alpha\beta} * BN \end{cases}, \quad \forall \theta^x \in \left\{FA^{Dd}, FA^{Dn}\right\}, \beta \in G^p \tag{43}$$

5. Maximum goods transformation

Equations (41), (42) and (43) ensure only that if goods transformation occurs, the sum of $gotr_{\theta^x \alpha\beta}$ equals or exceeds one. Consequently, it is necessary to limit the maximum number of goods transformations, including those from modular components into semi-products, from modular components into finished products, and from semi-products into finished products. Thus, these constraints are expressed as Eqs. (44), (45) and (46), respectively.

$$\sum_{\theta^x \in \{FA^M, FA^{Dd}, FA^{Dn}\}} \sum_{\alpha \in G^r} gotr_{\theta^x \alpha\beta} \le \sum_{\alpha \in G^r} BOM_{\alpha\beta}, \quad \forall \beta \in G^s \tag{44}$$

$$\sum_{\theta^x \in \{FA^M, FA^{Dd}, FA^{Dn}\}} \sum_{\alpha \in G^r} gotr_{\theta^x \alpha\beta} \le \sum_{\alpha \in G^r} BOM_{\alpha\beta}, \quad \forall \beta \in G^p \tag{45}$$

$$\sum_{\theta^x \in \{FA^{Dd}, FA^{Dn}\}} \sum_{\alpha \in G^s} gotr_{\theta^x \alpha\beta} \le \sum_{\alpha \in G^s} BOM_{\alpha\beta}, \quad \forall \beta \in G^p \tag{46}$$

6. Assignment of goods

Each modular component can only be used once. Only one of two manufacturing procedures, including from modular components into either semi-products or finished products, can be used. Therefore, the corresponding constraint is given by Eq. (47).

$$\sum_{\theta^x \in \{FA^M, FA^{Dd}, FA^{Dn}\}} \sum_{\beta \in G^s} gotr_{\theta^x \alpha\beta} + \sum_{\theta^x \in \{FA^M, FA^{Dd}, FA^{Dn}\}} \sum_{\omega \in G^p} gotr_{\theta^x \alpha\omega} \le 1, \quad \forall \alpha \in G^r \tag{47}$$

Since each semi-product can only be used once, the corresponding constraint is given by Eq. (48).

$$\sum_{\theta^x \in \{FA^{Dd}, FA^{Dn}\}} \sum_{\beta \in G^p} gotr_{\theta^x \alpha \beta} \leq 1, \quad \forall \alpha \in G^s \tag{48}$$

Finished products can be transferred among DCs, but one finished product only can be assigned once to a brand company. Restated, one company can only receive one unique finished product during the assignment process. Accordingly, the corresponding constraint is given by Eq. (49).

$$\sum_{\theta^x \in FA^{DC}} \sum_{\lambda^y \in FA^B} \sum_{m \in \Omega(\theta^x, \lambda^y)} qu_{\theta^x \lambda^y m \alpha} = 1, \quad \forall \alpha \in G^p \tag{49}$$

7. Brand company requirements

To meet brand company requirements, the corresponding constraint is given by Eq. (50).

$$\sum_{\theta^x \in FA^{DC}} \sum_{m \in (\theta^x, \lambda^y)} \sum_{\alpha \in G^p} qu_{\theta^x \lambda^y m \alpha} = BR_{\lambda^y}, \quad \forall \lambda^y \in FA^B \tag{50}$$

8. Capacity of chain members

In addition to vender capacity to supply modular components (Eq. (51)), there are five capacities of internal supply chain members for goods transformation, including from modular components into semi-products, from modular components into finished products, from semi-products into finished products, simple process of semi-products and simple process of finished products. Accordingly, the corresponding constraints on five capacities of internal supply chain members are expressed as Eqs. (52), (53), (54), (55) and (56), respectively.

$$\sum_{\lambda^y \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\}} \sum_{m \in \Omega(\theta^x, \lambda^y)} \sum_{\alpha \in G^r} qu_{\theta^x \lambda^y m \alpha} \le VC_{\theta^x}, \quad \forall \theta^x \in FA^V \tag{51}$$

$$\sum_{\alpha \in G^s} \sum_{f \in SN_O^{rs}} gt_{\theta^x \alpha f} \le RSA_{\theta^x}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\} \tag{52}$$

$$\sum_{\alpha \in G^p} \sum_{f \in SN_O^{rp}} gt_{\theta^x \alpha f} \le RPA_{\theta^x}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\} \tag{53}$$

$$\sum_{\alpha \in G^p} \sum_{f \in SN_O^{sp}} gt_{\theta^x \alpha f} \le SPA_{\theta^x}, \quad \forall \theta^x \in \left\{FA^{Dd}, FA^{Dn}\right\} \tag{54}$$

$$\sum_{\alpha \in G^s} \sum_{f \in SN_O^{ss}} gt_{\theta^x \alpha f} \le SSA_{\theta^x}, \quad \forall \theta^x \in \left\{FA^{DC}\right\} \tag{55}$$

$$\sum_{\alpha \in G^p} \sum_{f \in SN_O^{pp}} gt_{\theta^x \alpha f} \le PPA_{\theta^x}, \quad \forall \theta^x \in \left\{FA^{DC}\right\} \tag{56}$$

9. Subtour breaking constraints

Since goods can transfer among DCs, Eq. (57) prohibits a formation of any subtour among them.

$$ord_{\theta^x \alpha} - ord_{\lambda^y \alpha} + NODE \sum_{m \in \Omega(\theta^x, \lambda^y)} qu_{\theta^x \lambda^y m \alpha} \le NODE - 1, \quad \forall \theta^x \ne \lambda^y \in FA^{DC}, \alpha \in \left\{G^s, G^p\right\} \tag{57}$$

10. Binary constraints

Constraints denoted by Eqs. (58), (59), (60), (61) and (62) indicate that those variables are binary.

$$gotr_{\theta^x \alpha \beta} \in \{0,1\}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\}, \alpha \in G^r, \beta \in G^s \tag{58}$$

$$gotr_{\theta^x \alpha \beta} \in \{0,1\}, \quad \forall \theta^x \in \left\{FA^M, FA^{Dd}, FA^{Dn}\right\}, \alpha \in G^r, \beta \in G^p \tag{59}$$

$$gotr_{\theta^x \alpha \beta} \in \{0,1\}, \quad \forall \theta^x \in \left\{FA^{Dd}, FA^{Dn}\right\}, \alpha \in G^s, \beta \in G^p \tag{60}$$

$$gt_{\theta^x \alpha f} \in \{0,1\}, \quad \forall \theta^x \in FA^I, \alpha \in G, f \in SN \tag{61}$$

$$qu_{\theta^x \lambda^y m \alpha} \in \{0,1\}, \quad \forall \theta^x \in FA, \lambda^y \in FA, m \in \Omega, \alpha \in G \tag{62}$$

11. Non-negative constraints

Constraints denoted by Eqs. (63) and (64) indicate that operating income variables are non-negative variables.

$$oi^{+}_{\theta^x} \geq 0, \quad \forall \theta^x \in FA^I \tag{63}$$

$$oi^{-}_{\theta^x} \geq 0, \quad \forall \theta^x \in FA^I \tag{64}$$

CHAPTER 6 NUMERICAL ILLUSTRATION

The numerical illustration discussed includes the following: (1) the basic scenario, (2) sensitivity analysis, (3) extended scenarios, (4) discussion.

6.1 The Basic Scenario

To test the applicability and the solvability of the proposed model, a simplified numerical study was conducted by interview. Figure 6.1 depicts the global network used in the numerical study and Table 6.1 outlines the main characteristics of the basic scenario. It should be noted that country 1 has a lower logistics cost (such as deep processing costs) and greater processing capacity (such as deep processing capacity) than countries 2 and 3 in the basic scenario.

The scenario considered in this study involves a simplified case. In this study, country 1 can be taken to represent China, country 2 can be regarded as Taiwan, and country 3 can be treated as Hong Kong. The scenario involves brand companies requesting global manufacturers to distribute three orders of finished products to FA_{11}^{B} and two orders to FA_{12}^{B}. FA_{11}^{B} and FA_{12}^{B} are DCs or warehouses owned by the brand companies. Vendors (FA_{1}^{V}, FA_{2}^{V}) send modular components to manufacturing centers (FA_{3}^{M}), deep processing DCs (FA_{7}^{Dd}, FA_{8}^{Dd}) or non-bonded DCs (FA_{9}^{Dm}, FA_{10}^{Dn}) to transform modular components into semi-products or finished products. Semi-products or finished products can then be transferred between various kinds of DCs (FA_4^{Ds}, FA_5^{Ds}, FA_6^{Ds}, FA_7^{Dd}, FA_8^{Dd}, FA_9^{Dm}, FA_{10}^{Dn}) to identify the optimal tax savings routes and manufacturing procedures. Notably, internal supply chain members in international logistics zones (FA_4^{Ds}, FA_5^{Ds}, FA_7^{Dd}, FA_8^{Dd}) are tax exempt.

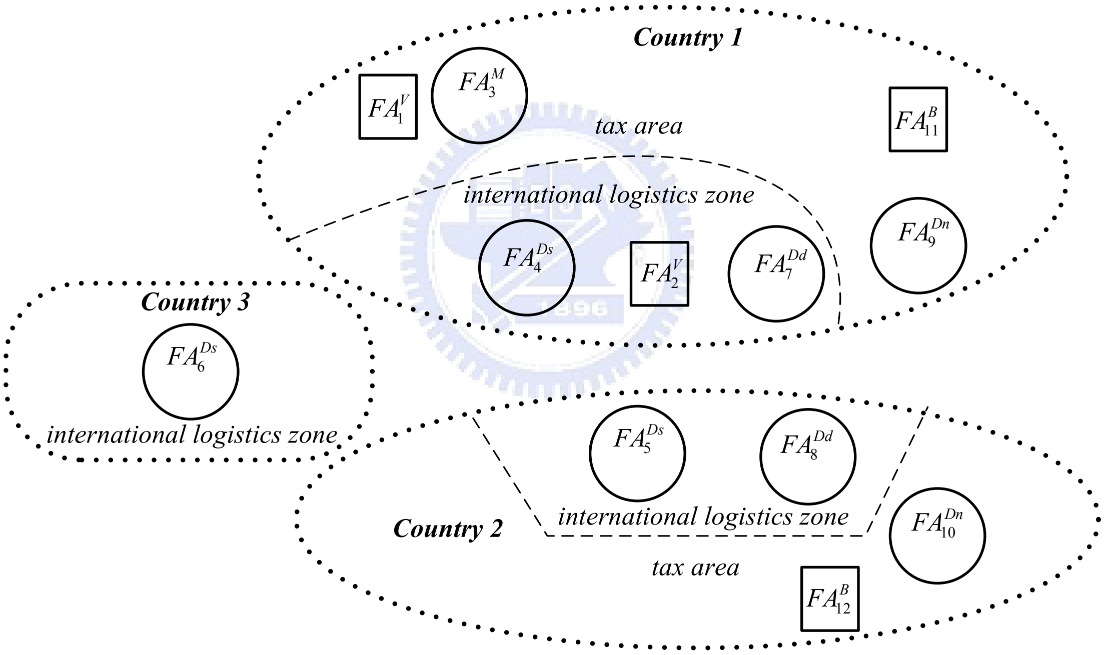

Figure 6.1 Global network used for the numerical study

Table 6.1 Main characteristics of the basic scenario

Characteristics	Design Value
Set of supply chain members	$FA^{V}=\{1,2\}$; $FA^{M}=\{3\}$; $FA^{Ds}=\{4,5,6\}$; $FA^{Dd}=\{7,8\}$; $FA^{Dn}=\{9,10\}$; $FA^{B}=\{11, 12\}$;
Set of goods	$G^{r}=\{1,\ldots,20\}$; $G^{s}=\{21,\ldots,30\}$; $G^{p}=\{31,\ldots,35\}$;
Set of countries	$N=\{1,2,3\}$
Set of simple and deep process product lines	$SN_I^{rs}=\{1\}$; $SN_I^{rp}=\{2\}$; $SN_I^{sp}=\{3\}$; $SN_I^{ss}=\{4\}$; $SN_I^{pp}=\{5\}$; $SN_O^{rs}=\{6\}$; $SN_O^{rp}=\{7\}$; $SN_O^{sp}=\{8\}$; $SN_O^{ss}=\{9\}$; $SN_O^{pp}=\{10\}$;
Set of transportation modes	$\Omega=\{$air transportation: 1, sea transportation: 2, truck: 3$\}$
Required finished products	BR_{11^1}=3 (orders); BR_{12^2}=2 (orders)
Equivalent of goods	BOM_{rs}=2; BOM_{sp}=2; BOM_{rp}=4

Note: per order of 100 goods.

Figure 6.2 displays five main patterns of the numerical results of logistics behavior. First, modular components were shipped from vendor (No.2) to deep processing DC (No.7) or deep processing DC (No.8). Second, deep processing take place at deep processing DC (No.7) or deep processing DC (No.8) to transform modular components into semi-products. Third, semi-products were shipped from deep processing DC (No.7) to another deep processing DC (No.8), and simple processing of semi-products then took place at deep processing DC (No.8). Fourth, semi-products were shipped from deep processing DC (No.7) to non-bonded DC (No.9) or from deep processing DC (No.8) to non-bonded DC (No.10) for further transformation of semi-products into finished products. Finally, finished products are shipped from non-bonded DC (No.9) to brand company (No.11) or from non-bonded DC (No.10) to brand company (No.12). Furthermore, some internal supply members operate at a profit (No.7, No.9, No.10), and others operate at a loss (No.3, No.4, No.5, No.6, No.8).

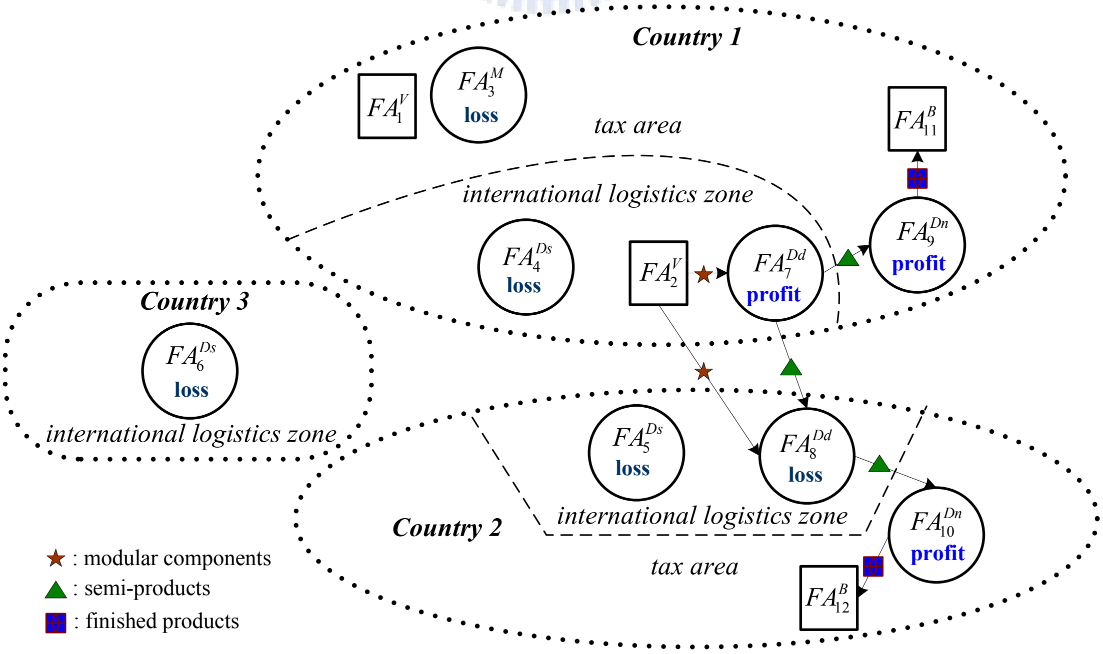

Figure 6.2 Numerical results for logistics behavior

More precisely, Table 6.2 shows the numerical results of logistics behavior, and an example of the steps involved in created the finished product (NO.33) for the requirement of brand company (NO.12). Modular components (NO.6 and NO.10) were first shipped from vender (NO.2) to deep processing DC (NO.8), and the goods were then transformed from modular components (NO.6 and NO.10) into semi-product (NO.23) at deep processing DC (NO.8), as depicted in Figure 6.3. Meanwhile, modular components (NO.7 and NO.13) were shipped from vendor (NO.2) to deep processing DC (NO.7), and goods transformation from modular components (NO.7 and NO.13) into semi-product (NO.24) took place at deep processing DC (NO.7). Afterward, semi-product (NO.24) was shipped from deep processing DC (NO.7) to another deep processing DC (NO.8), and simple processing of semi-products then took place at deep processing DC (NO.8), as depicted in Figure 6.3. Next, semi-products (NO.23 and NO.24) were shipped from deep processing DC (NO.8) to non-bonded DC (NO.10) for further transformation of semi-products into finished product (NO.33). Finally, the finished product (NO.33) was shipped from a non-bonded DC (NO.10) to a brand company (NO.12).

Table 6.2 Summary of the numerical results for logistics behavior

1. Behavior of P31 for delivering finished products to brand company 11
- *R*5-*S*21: qu(2, 7, 1, 5)➔gt(7, 5, 1)➔gotr(7, 5, 21)➔gt(7, 21, 6)
- *R*11-*S*21: qu(2, 7, 1, 11)➔gt(7, 11, 1)➔gotr(7, 11, 21)➔gt(7, 21, 6)
- *R*8-*S*30: qu(2, 7, 1, 8)➔gt(7, 8, 1)➔gotr(7, 8, 30) ➔gt(7, 30, 6)
- *R*20-*S*30: qu(2, 7, 1, 20)➔gt(7, 20, 1)➔gotr(7, 20, 30) ➔gt(7, 30, 6)
- *S*21-*P*31: qu(7, 9, 3, 21)➔gt(9, 21, 3)➔gotr(9, 21, 31)➔gt(9, 31, 8)
- *S*30-*P*31: qu(7, 9, 3, 30)➔gt(9, 30, 3)➔gotr(9, 30, 31)➔gt(9, 31, 8)
- *P*31: qu(9, 11, 3, 31)

2. Behavior of P32 for delivering finished products to brand company 11
- *R*4-*S*22: qu(2, 7, 1, 4)➔gt(7, 4, 1) ➔gotr(7, 4, 22) ➔gt(7, 22, 6)
- *R*16-*S*22: qu(2, 7, 1, 16)➔gt(7, 16, 1) ➔gotr(7, 16, 22) ➔gt(7, 22, 6)
- *R*17-*S*26: qu(2, 7, 1, 17)➔gt(7, 17, 1) ➔gotr(7, 17, 26) ➔gt(7, 26, 6)
- *R*18-*S*26: qu(2, 7, 1, 18)➔gt(7, 18, 1) ➔gotr(7, 18, 26) ➔gt(7, 26, 6)
- *S*22-*P*32: qu(7, 9, 3, 22)➔gt(9, 22, 3)➔gotr(9, 22, 32)➔gt(9, 32, 8)
- *S*26-*P*32: qu(7, 9, 3, 26)➔gt(9, 26, 3)➔gotr(9, 26, 32)➔gt(9, 32, 8)
- *P*32: qu(9, 11, 3, 32)

3. Behavior of P33 for delivering finished products to brand company 12
- *R*6-*S*23: qu(2, 8, 1, 6)➔gt(8, 6, 1) ➔gotr(8, 6, 23) ➔gt(8, 23, 6)
- *R*10-*S*23: qu(2, 8, 1, 10)➔gt(8, 10, 1) ➔gotr(8, 10, 23) ➔gt(8, 23, 6)
- *R*7-*S*24: qu(2, 7, 1, 7)➔gt(7, 7, 1)➔gotr(7, 7, 24)➔gt(7, 24, 6)
- *R*13-*S*24: qu(2, 7, 1, 13)➔gt(7, 13, 1)➔gotr(7, 13, 24)➔gt(7, 24, 6)
- *S*24-*S*24: qu(7, 8, 2, 24)➔gt(8, 24, 4)➔gt(8, 24, 9)
- *S*23-*P*33: qu(8, 10, 3, 23)➔gt(10, 23, 3)➔gotr(10, 23, 33)➔gt(10, 33, 8)
- *S*24-*P*33: qu(8, 10, 3, 24)➔gt(10, 24, 3)➔gotr(10, 24, 33)➔gt(10, 33, 8)
- *P*33: qu(10, 12, 3, 33)

4. Behavior of P34 for delivering finished products to brand company 11
- *R*12-*S*25: qu(2, 7, 1, 12)➔gt(7, 12, 1) ➔gotr(7, 12, 25) ➔gt(7, 25, 6)
- *R*15-*S*25: qu(2, 7, 1, 15)➔gt(7, 15, 1) ➔gotr(7, 15, 25) ➔gt(7, 25, 6)
- *R*3-*S*27: qu(2, 7, 1, 3)➔gt(7, 3, 1) ➔gotr(7, 3, 27) ➔gt(7, 27, 6)
- *R*14-*S*27: qu(2, 7, 1, 14)➔gt(7, 14, 1) ➔gotr(7, 14, 27) ➔gt(7, 27, 6)
- *S*25-*P*34: qu(7, 9, 3, 25)➔gt(9, 25, 3)➔gotr(9, 25, 34) ➔gt(9, 34, 8)
- *S*27-*P*34: qu(7, 9, 3, 27)➔gt(9, 27, 3)➔gotr(9, 27, 34) ➔gt(9, 34, 8)
- *P*34: qu(9, 11, 3, 34)

5. Behavior of P35 for delivering finished products to brand company 12
- *R*1-*S*28: qu(2, 8, 1, 1)➔gt(8, 1, 1) ➔gotr(8, 1, 28) ➔gt(8, 28, 6)
- *R*9-*S*28: qu(2, 8, 1, 9)➔gt(8, 9, 1) ➔gotr(8, 9, 28) ➔gt(8, 28, 6)
- *R*2-*S*29: qu(2, 7, 1, 2)➔gt(7, 2, 1)➔gotr(7, 2, 29)➔gt(7, 29, 6)
- *R*19-*S*29: qu(2, 7, 1, 19)➔gt(7, 19, 1)➔gotr(7, 19, 29)➔gt(7, 29, 6)
- *S*29-*S*29: qu(7, 8, 2, 29)➔gt(8, 29, 4)➔gt(8, 29, 9)
- *S*28-*P*35: qu(8, 10, 3, 28)➔gt(10, 28, 3)➔gotr(10, 28, 35)➔gt(10, 35, 8)
- *S*29-*P*35: qu(8, 10, 3, 29)➔gt(10, 29, 3)➔gotr(10, 29, 35)➔gt(10, 35, 8)
- *P*35: qu(10, 12, 3, 35)

Note: R indicates modular components; S indicates semi-products; P indicates finished products. One dash linking two goods means deep process (e.g., *R*5-*S*26) or simple process (e.g., *S*21-*S*21) while single goods indicates shipping goods (e.g., *P*31). Here, qu, gt and $gotr$ are main decision variables. Four terms within the qu bracket represent former member (origin), latter member (destination), transportation mode and goods, respectively. Three terms within the gt bracket denote chain member, goods and product line, respectively. Three terms within the $gotr$ bracket indicate chain member, ancestor goods, and descendant goods, respectively.

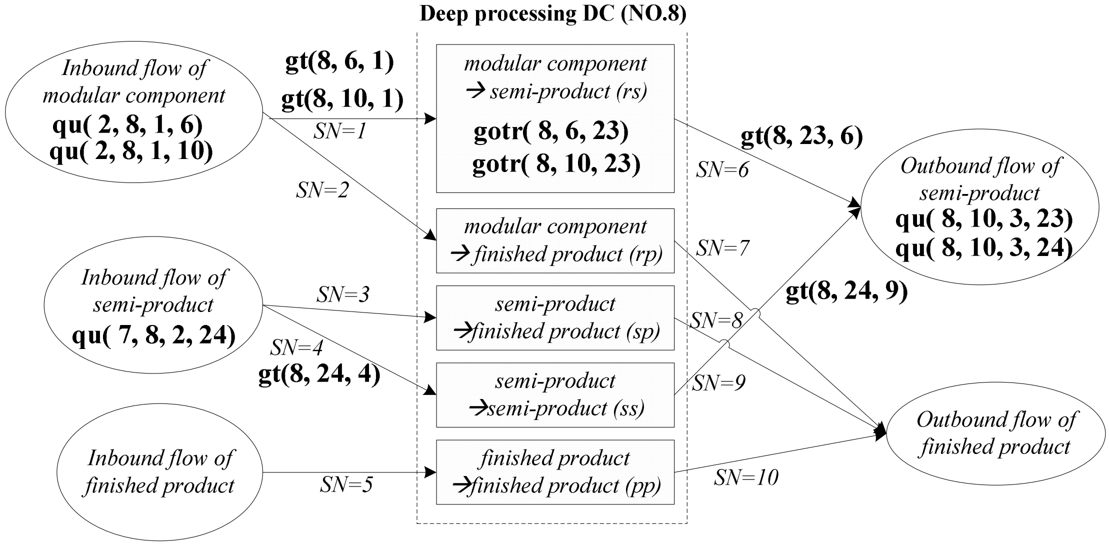

Figure 6.3 An illustrative example of the deep process and the simple process

6.2 Sensitivity Analysis

Figure 6.4 presents the results of the sensitivity analysis conducted with varying tax parameters such as corporate tax rates, duties, VAT rates and VAT drawback rates.

As expected, lower corporate tax rates, lower VAT rates and lower duty rates all tended to increase after-tax profit. Herein, corporate tax rate exerts the largest influence on after-tax profit. Notably, the VAT drawback rate does not affect after-tax profit, since lack of logistics behavior meets the charge condition of VAT drawback rate in the basic scenario. This finding also reveals that manufacturers can avoid government regulation strategies related to VAT drawback rates by operating in international logistics zones.

Overall, the sensitivity analysis demonstrates the robustness of the proposed model, and most tax factors are sensitive to after-tax profit. The above tax factors would be of importance to manufacturers seeking to maximize profit through global logistics strategies.

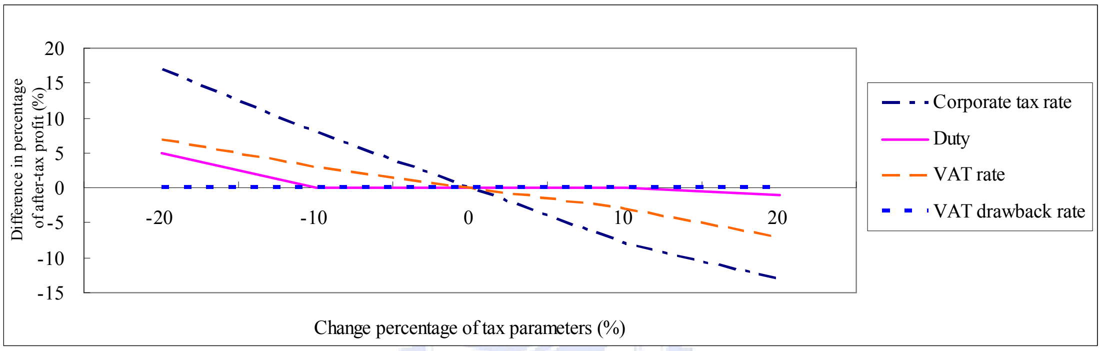

Figure 6.4 Sensitivity of after-tax profit with respect to variant tax parameters

6.3 Extended Scenarios

To further examine logistics behavior, three extended scenarios and their numerical results are briefly narrated as follows. First, if tax areas were exempt from corporate tax as international logistics zones, most finished products would be directly manufactured at non-bonded DCs located close to brand companies (extended scenario) rather than at deep processing DCs in international logistics zones (basic scenario). Second, if tax areas were exempted from import duty as international logistics zones, most finished products would be directly manufactured in international logistics zones (extended scenario) rather than in tax areas (basic scenario). Third, if country 2 has the same logistics cost and processing capacity as country 1, then semi-products would not be shipped from country 1 to country 2 (extended scenario).

6.4 Discussions

Based on the numerical results of logistics behavior mentioned above, some important findings are summarized and discussed as follows.

First of all, most semi-products are manufactured in international logistics zones. The main reason for this result may be that goods manufactured in those zones are exempt from corporate tax.

Secondly, most domestic (non-bonded) DCs import semi-products from international logistics zones, since import duties are lower for semi-products than for finished products. A similar concept was discussed in Simchi-Levi *et al*. (2003).

Thirdly, some internal supply members operate at a profit, but others operate at a loss. This occurs mainly because the objective function maximizes after-tax profit for global internal supply chain members.

Fourthly, VAT drawback rate does not affect after-tax profit. This lack of influence results mainly from no logistics related behavior meeting the conditions for charging VAT drawback. Therefore, manufacturers operate in international logistics zones to avoid government regulation of VAT drawback rate.

Finally, the model demonstrates that most manufacturing behavior occurs in country 1, and semi-products are then shipped from country 1 to country 2. In reality, this may be owing to that manufacturers relocated their main processing capacity to low-cost zones (e.g. China) and has a lower processing capacity in the proximity of customers or in R&D zones (e.g. Taiwan). Similar situations are apparent elsewhere (Chia *et al.*, 2001; Chia *et al.*, 2002; Sheu, 2003).

CHAPTER 7 CONCLUSIONS

The conclusions are narrated as follows: (1) general conclusions; (2) further extensions.

7.1 General Conclusions

The complex global production-distribution network involves nodal location features of tax areas and international logistics zones, manufacturing procedures of simple process and deep process in these nodes, as well as transportation arcs. This study presented several tax savings approaches and developed a tax savings model for the emerging global production-distribution network. The numerical illustration demonstrates that the model is valid and viable as an analytical tool for global manufactures. The major decision-making parameters can be tailored to specific global manufacturers.

The numerical illustration reveals the following crucial findings. First, manufacturers can produce goods in international logistics zones to save corporate tax. Second, manufacturers can import ancestor goods (e.g. semi-products) with lower duty rates and transform them into descendant goods (e.g. finished products) in tax areas to save duty. Third, manufacturers can operate in international logistics zones to avoid government regulation of VAT drawback rate. Finally, most manufacturing behavior occurs in zones with lower logistics costs and greater processing capacity to maximize their global profit.

This study differs from previous studies addressing profit-maximizing problems in several ways. First, this study examined three primary tax factors associated with operating income—import duty, value added tax and corporate tax—via in-depth interviews with global manufacturers. Furthermore, tax savings approaches for the emerging global production-distribution network were also discussed. Second, the tax savings model for the emerging global production-distribution network helps manufacturers identify solutions that maximize after-tax profit. The proposed model can determine the optimal tax savings route and manufacturing procedure for each order. For tax savings, the proposed model allows goods free transfer among processing DCs. Additionally, three principal tax factors are considered simultaneously in the proposed model. Global manufacturers can develop strategies using the proposed model for maximizing preferential tax treatment in international logistics zones to achieve tax savings. Moreover, the proposed model identifies the critical logistics behavior associated with tax savings. The proposed model may stimulate further research in the field of global logistics and may help address issues regarding tax savings and international logistics zones.

7.2 Extensions to future research

Future studies may also incorporate quotas, certificate of origin and local content into the tax savings model. The model may also be extended to a product family and its bill-of-materials (BOM). Moreover, large-scale instances of profit-maximizing problems in a numerical study should be carefully generated to approximate reality as much as possible. The continuing relevance of the proposed model is expected in further studies.

REFERENCES

Albino, V., Izzo, C., Kühtz, S., 2002. Input–output models for the analysis of a local/global supply chain. International Journal of Production Economics 78 (2), 119-131.

Aliev, R.A., Fazlollahi, B., Guirimov, B.G., Aliev, R.R., 2007. Fuzzy-genetic approach to aggregate production–distribution planning in supply chain management. Information Sciences 177 (20), 4241-4255.

Arntzen, B., Brown, G., Harrison, T., Trafton, L., 1995. Global supply chain management at digital equipment corporation. Interfaces 21 (1), 69-93.

Avittathur, B., Shah, J., Gupta, O. K., 2005. Distribution centre location modelling for differential sales tax structure. European Journal of Operational Research 162 (1), 191-205.

Balaji, K., Viswanadham, N., 2008. A tax integrated approach for global supply chain network planning. IEEE Transactions on Automation Science and Engineering 5 (4), 587- 596.

Barbarosoglu, G., Özgür, D., 1999. Hierarchical design of an integrated production and 2-echelon distribution system. European Journal of Operational Research 118 (3), 464-484.

Birkinshaw, J.M., Morrison, A.J., 1995. Configurations of strategy and structure in subsidiaries of multinational corporations. Journal of International Business Studies 26 (4), 729-754.

Björk, K.-M., Carlsson, C., 2007. The effect of flexible lead times on a paper producer. International Journal of Production Economics 107 (1), 139-150.

Boissière, J., Frein, Y., Rapine, C., 2008. Lot-sizing in a serial distribution system with capacitated in-system production flow. International Journal of Production Economics 112 (1), 483-494.

Bowersox, D.J., Closs, D.J., 1996. Logistical Management: The Integrated Supply Chain Process. McGraw-Hill, Singapore.

Cavusgi, S.T., Yeniyurt, S., Townsend, J.D., 2004. The framework of a global company: A conceptualization and preliminary validation. Industrial Marketing Management 33 (8), 711-716.

Chia, K.-C., Feng, C.-M., Chang, C.-J., 2001. The effects of global logistics strategies on international freight transportation demand. Journal of Eastern Asia Society for Transportation Studies 6 (6), 343-358.

Chan, F.T.S., Chung, S.H., Wadhwa, S., 2005. A hybrid genetic algorithm for production and distribution. Omega 33 (4), 345-355.

Chen, Z.-L., Vairaktarakis, G.L., 2005. Integrated scheduling of production and distribution operations. Management Science 51 (4), 614-628.

Chia, K.-C., Feng, C.-M., Chang, C.-J., 2002. Survey analysis of supply chain adjustment for Taiwanese information technology firms. Transport Reviews 22 (4), 473-497.

DHL, 2006. China logistics service overview. Greater China Cross Trade Customer Seminar, Taipei.

Eden, L., Rodriguez, P., 2004. How weak are the signals? International price indices and multinational enterprises. Journal of International Business Studies 35 (1), 61-74.

Elmuti, D., Minnis, W., Abebe, M. 2008. Longitudinal assessment of an integrated industrial supply chain. Supply Chain Management: An International Journal 13 (2), 151-159.

Fandel, G., Stammen, M., 2004. A general model for extended strategic supply chain management with emphasis on product life cycles including development and recycling. International Journal of Production Economics 89 (3), 293-308.

Feng, C.-M., Wu, P.-J., Chia, K.-C., 2009. A hybrid fuzzy integral decision-making model for locating manufacturing centers in China: a case study. European Journal of Operational Research, doi:10.1016/j.ejor.2008.12.004.

Frohlich, M.T., Westbrook, R. 2001. Arcs of integration: an international study of supply chain strategies. Journal of Operations Management 19 (2) 2, 185-200.

Gjerdrum, J., Shah, N., Papageorgiou, L.G., 2002. Fair transfer price and inventory holding policies in two-enterprise supply chains. European Journal of Operational Research 143 (3), 582-599.

Goetschalckx, M., Vidal, C.J., Dogan, K., 2002. Modeling and design of global logistics systems: A review of integrated strategic and tactical models and design algorithms. European Journal of Operational Research 143 (1), 1-18.

Greis, N.P., Kasarda, J.D., 1997. Enterprise logistics in the information age. California Management Review 39 (3), 55-78.

Hahn, C.K., Duplaga, E.A., Hartley, J.L., 2000. Supply-chain synchronization: Lessons from Hyundai Motor Company. Interfaces 30 (4), 32-45.

Hameri, A.-P., Paatela, A., 2005. Supply network dynamics as a source of new business. International Journal of Production Economics 98 (1), 41-55.

Hammami, A., Burlat, P., Campagne, J.P., 2003. Evaluating orders allocation within networks of firms. International Journal of Production Economics 86 (3), 233-249.

Hiraki, S., 1996. Comparative analysis of ordering models for an international co-operative global complementary production system. International Journal of Production Economics 44 (1-2), 105-117.

Kerbache, L., MacGregor Smith, J., 2004. Queueing networks and the topological design of supply chain systems. International Journal of Production Economics 91 (3), 251-272.

Lakhal, S.Y., H'Mida, S. Venkatadri, U., 2005. A market-driven transfer price for distributed products using mathematical programming. European Journal of Operational Research 162 (3), 690-699.

Lamothe, J., Hadj-Hamou, K., Aldanondo, M., 2006. An optimization model for selecting a product family and designing its supply chain. European Journal of Operational Research 169 (3), 1030-1047.

Lee, H., Yang, H. M., 2003. Strategies for a global logistics and economic hub: Incheon International Airport. Journal of Air Transport Management 9 (2), 113-121.

Lee, K.-L., 2007. Analyzing the competitive relations among the location in the Asia-pacific region for developing the re-export type of global logistics hub. Journal of Marine Science and Technology 15 (3), 187-200.

Lee, Y.H., Kim, S.H., 2002. Production–distribution planning in supply chain considering capacity constraints. Computers and Industrial Engineering 43 (1-2), 169-190.

Lin, S.-C., Liang, G.-S., Lee, K.-L., 2006. Applying fuzzy analytic hierarchy process in location mode of international logistics on airports competition evaluation. Journal of Marine Science and Technology 14 (1), 25-38.

Lu, C.-S., 2003. Market segment evaluation and international distribution centers. Transportation Research Part E: Logistics and Transportation Review 39 (1), 49-60.

Lu, C.-S., Yang, C.-C., 2007. An evaluation of the investment environment in international logistics zones: A Taiwanese manufacturer's perspective. International Journal of Production Economics 107 (1), 279-300.

Mattsson, L.-G., 2003. Reorganization of distribution in globalization of markets: the dynamic context of supply chain management. Supply Chain Management: An International Journal 8 (5), 416-426.

Meixell, M.J., Gargeya, V.B., 2005. Global supply chain design: A literature review and critique. Transportation Research Part E: Logistics and Transportation Review 41 (6), 531-550.

Mezgár, I., Kovács, G.L., Paganelli, P., 2000. Co-operative production planning for small- and medium-sized enterprises. International Journal of Production Economics 64 (1-3), 37-48.

Miles, R.E., Snow, C.C., 2007. Organization theory and supply chain management: An evolving research perspective. Journal of Operations Management 25 (2), 459-463.

Nonino, F., Panizzolo, R., 2007. Integrated production/distribution planning in the supply chain: the Febal case study. Supply Chain Management: An International Journal 12 (2), 150-163.

Oum, T.H., Park, J.H., 2004. Multinational firms' location preference for regional distribution centers: focus on the Northeast Asian region. Transportation Research Part E: Logistics and Transportation Review 40 (2), 101-121.

Petersen, K.J., Handfield, R.B., Ragatz, G.L., 2005. Supplier integration into new product development: coordinating product, process and supply chain design. Journal of Operations Management 23 (3-4), 371-388.

Porter, M.E., 1998. Clusters and the new economics of competition. Harvard Business Review 76 (6), 77-90.

Power, D., 2005. Supply chain management integration and implementation:

a literature review. Supply Chain Management: An International Journal 10 (4), 252-263.

Prasad, S., Sounderpandian, J., 2003. Factors influencing global supply chain efficiency: implications for information systems. Supply Chain Management: An International Journal 8 (3), 241-250.

Prater, E., Ghosh, S., 2006. A comparative model of firm size and the global operational dynamics of U.S. firms in Europe. Journal of Operations Management 24 (5), 511-529.

Samaranayake, P., 2005. A conceptual framework for supply chain management: a structural integration. Supply Chain Management: An International Journal 10 (1), 47-59.

Selim, H., Araz, C., Ozkarahan, I., 2008. Collaborative production–distribution planning in supply chain: A fuzzy goal programming approach. Transportation Research Part E: Logistics and Transportation Review 44 (3), 396-419.

Sheu, J.-B., 2003. Locating manufacturing and distribution centers: An integrated supply chain-based spatial interaction approach. Transportation Research Part E: Logistics and Transportation Review 39 (5), 381-397.

Sheu, J.-B., 2004. A hybrid fuzzy-based approach for identifying global logistics strategies. Transportation Research Part E: Logistics and Transportation Review 40 (1), 39-61.

Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., 2008. Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies. McGraw-Hill, New York.

Soosay, C.A., Hyland, P.W., Ferrer, M., 2008. Supply chain collaboration: capabilities for continuous innovation. Supply Chain Management: An International Journal 13 (2), 160-169.

Swafford, P.M., Ghosh, S., Murthy, N., 2006. The antecedents of supply chain agility of a firm: Scale development and model testing. Journal of Operations Management 24 (2), 170-188.

Teng, J.-Y., Lee, K.-L., Huang, W.-C., 2007. A fuzzy multicriterion Q-analysis model for international logistic-park location selection. Journal of Marine Science and Technology 15 (2), 89-103.

Van Mieghem, J.A., 1999. Coordinating investment, production, and subcontracting. Management Science 45 (7), 954-971.

Vidal, C.J., Goetschalckx, M., 1997. Strategic production-distribution models: a critical review with emphasis on global supply chain models. European

Journal of Operational Research 98 (1), 1-18.

Vidal, C.J., Goetschalckx, M., 1998. A heuristic for the design of global supply chains with transfer pricing and transportation cost allocation. Research Report, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia.

Vidal, C.J., Goetschalckx, M., 2000. Modeling the effect of uncertainties on global logistics systems. Journal of Business Logistics 21 (1), 95-120.

Vidal, C.J., Goetschalckx, M., 2001. A global supply chain model with transfer pricing and transportation cost allocation. European Journal of Operational Research 129 (1), 134-158.

Vila, D., Martel, A., Beauregard, R., 2006. Designing logistics networks in divergent process industries: A methodology and its application to the lumber industry. International Journal of Production Economics 102 (2), 358-378.

Yan, H., Yu, Z., Cheng, T.C.E., 2003. A strategic model for supply chain design with logical constraints: formulation and solution. Computers and Operations Research 30 (14), 2135-2155.

Zhai, E., Shi, Y., Gregory, M., 2007. The growth and capability development of electronics manufacturing service (EMS) companies. International Journal of Production Economics 107 (1), 1-19.

APPENDIX: VITA

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II. Personal Traits

1. Height:

   170cm

2. Weight:

   62kg

3. Hair:

   Black

4. Eye:

   Brown

5. Gender:

   Male

6. Birth date:

   Dec. 22, 1979

7. Birth place:

   Hsinchu

8. Blood type:

   B

1. EDUCATION

A. **Ph.D.**, Institute of Traffic and Transportation, National Chiao Tung University, Taipei, Taiwan, June 2009.

Advisor: Cheng-Min Feng

Dissertation: A tax savings model for managing a global production-distribution supply chain

B. **M.S.**, Department of Traffic and Transportation Engineering and Management, Feng Chia University, Taichung, Taiwan, June 2004.

Advisor: Ker-Tsung Lee

Thesis: The Planning and Design of the Missioned Taxipooling on Feeder System

C. **B.S.**, Departmant of Transportation Technology and Logistics Management, Chung Hua University, Hsinchu, Taiwan, June 2002.

Advisor: Jau-Ming Su

Thesis: Application of AVL to Formulate an Automatic Surround and Interception Algorithm－The Case of Hsin-Chu City

2. RESEARCH EXPERIENCE

Reviewer for Supply Chain Management: an International Journal [SSCI] (2008~)

3. TESCHING EXPERIENCE

Lecturer for Soochow University, Department of Business Administration (2009~)

4. PUBLISHION

A. Feng, C.-M., Wu, P.-J., 2009. A tax savings model for the emerging global manufacturing network. *International Journal of Production Economics*, doi:10.1016/j.ijpe.2009.05.019. (**SCI**, Impact Factor: 2.026) (NSC 95-2415-H009-003-MY2)

B. Feng, C.-M., Wu, P.-J., Chia, K.-C., 2009. A hybrid fuzzy integral decision-making model for locating manufacturing centers in China: a case study. *European Journal of Operational Research*, doi:10.1016/j.ejor.2008.12.004. (**SCI**, Impact Factor: 1.627) (NSC 93-2415-H-009-011)

C. Feng, C.-M., Tsai, Y.-H., Wu, P.-J., Lee, Y.-N., 2009. The development and evaluation of the national spatial structure alternatives of Taiwan. *City and Planning*, in press. (**TSSCI**, Accepted)

D. Lee, K.-T., Lin, D.-J., Wu, P.-J., 2005. Planning and design of a taxipooling dispatching system. *Transportation Research Record* 1903, 86-95. (**SCI,** Impact Factor: 0.259)

E. Su, J.-M., Wu, P.-J., 2004. Application of AVL to formulate an automatic surround and interception algorithm-the case of Hsin-Chu city. *Journal of the Chinese Institute of Transportation* 16 (1), 73-96. (**TSSCI**, **Best Paper Award**)

F. Feng, C.-M., Wu, P.-J., 2009. Approaches to managing global production-distribution logistics. *Journal of Marine Science and Technology*. (**SCI**) (Under Review) (NSC 95-2415-H009-003-MY2)

5. HONORS AND AWARDS

A. *Dissertation Writing Scholarship*, National Science Council, Taipei, Aug 2008-Jul 2009.

B. *Scholarship*, National Chiao Tung University, Taipei, 2007.

C. *Scholarship*, National Chiao Tung University, Taipei, 2006.

D. *Best Paper Award*, Chinese Institute of Transportation, Taipei, 2005.

E. *The Honor Member of the Phi Tau Phi Scholastic Honor Society*, The Phi Tau Phi Scholastic Honor Society, Taichung, June 2004.

F. *Academic Achievement Medal*, Feng Chia University, Taichung, June 2004.

G. *Scholarship*, Feng Chia University, Taipei, 2004.

H. *Scholarship*, Feng Chia University, Taipei, 2003.

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6. WORK EXPERIENCE

A. Researcher, The after tax profit-maximizing model for a transnational corporation with domestic and export logistics. *National Science Council*, Taipei, Aug 2006- Jul 2008.

B. Researcher, Enhancing the development of global logistics and free trade zone. *Council for Economic Planning and Development*, Taipei, Oct 2006-Feb 2007.

C. Researcher, The development and evaluation of the national spatial structure alternatives of Taiwan. *Urban and Rural Development Branch, Construction and Planning Agency, Ministry of the Interior*, Taipei, Jun 2005-Mar 2006.

D. Researcher, The preliminary project for trip forecast of large-scale exposition. *The Foundation of Taiwan exposition*, Taipei, Apr 2005-May 2005.

E. Researcher, The business model in China for Taiwanese manufacturing corporations. *National Science Council*, Taipei, Aug 2004-July 2005.

F. Researcher, The planning and design of geographic information system on guide sign systems (2/2). *Office of Science and Technology Advisors, Ministry of Transportation and Communications*, Taipei, Mar 2004-Aug 2004.

G. Researcher, The planning and design of geographic information system on guide sign systems (1/2). *Office of Science and Technology Advisors, Ministry of Transportation and Communications*, Taipei, Jun 2003-Jan 2004.

H. Researcher, Review and revise of rules for road traffic signs, traffic marks and traffic lights. *Institute of Transportation, Ministry of Transportation and Communications*, Taipei, Jun 2003-Aug 2004.

I. Researcher, Planning and development of core module for operation safety management and dispatch system of intelligent taxies. *Institute of Transportation, Ministry of Transportation and Communications*, Taipei, Feb 2003-Nov 2003.

J. Researcher, Research of intelligent dial-a-ride bus system. *National Science Council*, Taipei, Aug 2000-Jul 2001.