A Stochastic After-Taxes Optimisation Model to Support Distribution Network Strategies

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ABSTRACT

The paper proposes a stochastic model to integrate tax issues into strategic distribution network decisions. Specifically, this study will explore the role of distribution models in business profitability, and how to use the network design to deliver additional bottom-line results, using distribution centres located in different countries. The challenge is also to reveal how financial and tax knowledge can help logistic leaders improving the value to their companies under global solutions and sources of business net profitability in a dynamic environment. In particular, based on inventory distribution, the different configurations are analysed in order to support the selection of the most profitable operations network.

Keywords: stochastic model; market uncertainty; distribution network strategy; tax policy.

1. INTRODUCTION

Configuration of global supply chains has become a major challenge for firms as they aim to reduce costs, improve service level and expand their customer base in a competitive and uncertain business environment. In particular, managing multi-stage inventories by determining the number and best location of distribution centres to have; 2) maintaining the inventory level at each of the centres and 3) selecting the best possible transportation mode between manufacturing facilities and customer retail zones. An integrated approach is proposed to determine the number and location of distribution centres, while optimising net bottom-line results.

Uncertain sales with volume fluctuations, the ever-shorter product life cycles, and increasing product diversity, poses a challenge for supply network design using several subsidiaries or platforms and creates the need for flexibility in finding the best possible balance.

In times of tight financial resources, the present study using the experience extracted from a real flexibility assessment aiming net bottom-line results optimisation, will disclose the relevant role of supply chain managers in global financial business strategy, including the tax policy between different countries; for instance, aggressive tax policies will have consequences on the way exporting companies organize their structures, as the business can be conducted in a high number of tax jurisdictions. This is particularly important in European countries with unified customs rules but under different tax frames. Keeping this in mind, the role played by tax policy becomes increasingly interesting.

A network configuration normally addresses three issues: cost reduction, management control and after taxes profits optimisation. The trend towards globalisation is altering the way business is carried out. Global market forces the operating scheme and shape of supply chains, and the way products and services are brought to the market. The domestic market, particularly in small countries, limits the growth for companies that are under pressure to increase shareholder profitability. Such companies look for overseas opportunities to reduce costs and exploit new markets. At the end, the shareholder value is measured on a post-tax basis, which means, integrating tax impact, as such; business plan changes should be valued at bottom-line results. The supply chain models can be disturbed by unbalanced tax policies such as losses in some overseas subsidiaries that are not effectively used, while profits in other subsidiaries are subject to local aggressive taxes. Supply chain managers can determine where products are sourced from or manufactured, along with when and how they are distributed to end markets, moving volumes of goods across borders. These operational decisions have a direct impact on the company’s tax obligations.

In this study we emphasize two questions: (i) How should a multinational company split the inventory at different distribution points (subsidiaries), considering demand uncertainty and aiming a global bottom-line result optimisation? (ii) what is the best moment to change the network design from an actual status to a new situation. Following the research questions, we point that the primary goal of this study is to develop an integrated model for the distribution network decisions of a multinational corporation; and the second goal will be to illustrate the impact the tax system could have on distribution network design.

2. LITERATURE REVIEW

The first studies in reviewing the available literature, reported that the elements affecting a supply chain performance are related, among others, with inventory quantity and cost (e.g. [1, 2]); number of inventory points [3]; the location of distribution nodes [4, 5]; cost of distribution activities [6] and cost and mode of transportation and lead time [7]. According to Truong and Azadivar [8], the supply chain performance metrics are generally expressed in relation to one or more decision variables:
• location of plants, distribution centres and consolidation points most appropriate to serve customers requirements
• network structuring, involving centralization or decentralization of a distribution platform and decision about which nodes should be used
• number of echelons that will comprise a supply chain
• service sequence and volume including purchasing, production, and shipping at each node
• inventory level for raw material, work-in-process and finished products at each stage
• size of workforce or the extent of outsourcing as capacity options

It has been widely accepted that supply chain configuration, such as decisions on where inventory should be placed among nodes, can affect a company performance (e.g. [9]), which justifies the increasing importance of the theme in literature. However, despite the significant work done in domestic supply chain design under both deterministic and stochastic conditions, fewer researches have focused on the supply chains problematic under international conditions such as inventory costs, transportation costs and transfer price impact allied with countries tax regulations. In a multinational approach, each downstream distribution centre can be a subsidiary or a branch of the corporation company, located in different countries and subject to specific local tax rules.

In general, decision variables for supply chain configuration such as echelons location, transportation, inventory, demand, and product variety have been identified by various researches in the literature [10]. Typical objectives of supply chain configuration, besides cost minimization, are fair profit distribution, safe inventory levels, and maximum customer service level [11, 12], and according to Bantham, Celen and Kasouf [13] and Leger, Cassivi, Hadaya and Caya [14], supply chain configuration success is based on the relations among the members of the network.

For Alles and Datar [15], the global network must be designed and operated to recognise taxes, duties and transfer prices. Tsiakis, Shah and Pantelides [16] considered the design of a multi-echelon supply chain and determined the capacity and location decisions. In the same year, Graves and Willems [17], considered each node in the supply chain network as a potential stockpoint. According to Daley [18], the supply network configuration depends on the number of stages and where the nodes are located. Demand volatility also differs depending on the nodes location within the network; the further upstream a supply network node is placed (distant from the consumer) the higher risk of distortion in demand information. Such distortion can be reduced if downstream supply chain partners provide upstream nodes with reliable information on the status of their inventory [19].

Samaddar, Nargundkar and Daley [20] investigated the relationships between the design of a supply network and information sharing. Srai and Gregory [21] explored the impact of design on supply network capability, Creazza, Dallari and Melacini [22] developed a framework for selecting the most suitable logistics network configuration, with respect to some key logistics factors. Moser, Kern, Wohlfarth and Hartmann [23] presented theories to develop a benchmarking framework for supply network configuration analysis.

Recent studies have been concentrating on some relevant aspects that can be subdivided into strategic alignment, coordination of the nodes and design of the global logistics network [24, 25]. Kruger [26] explored the impact of international transport mode, consolidated nodes and the number of echelons on the configuration of global logistics networks while Cheong, Bhatnagar and Graves [27] evaluated the adoption of consolidation nodes to support worldwide deliveries, including shipping frequency. Zeng and Rossetti [28] analysed global transportation service categories, including inventory costs, as part of the decision making problem. For Hume [29] the complexity of a network model increases when multinational business units are added. Lovell, Saw and Stimson [30] proposed a framework for global network design based on product value and volume, and assuming that warehouses are characterised by a delivery area including one or more countries. Hsu and Zhu [31] found that the ultimate purpose of a product sold in the China market may have a significant impact on the chain structure preference.

According to Irving, Kilponen, Markarian and Klitgaard [32], Adams [33] and Banker [34] companies can benefit from adopting a joint fiscal and logistic perspective on supply chain design. Oster [35] argued that the location of functions, assets and risks are important factors for tax-effective supply chain management. Henkow and Normman [36] studied the impact of the tax system on supply chain design while Jackson and Loda [37] examined the influence of United States tax policy in branch forms of foreign companies. In the field of taxation, the focus has been on fiscal incentives, emission rights, waste charges and similar tax measures directed at activities having an adverse environmental impact [38]. Some contributions on legal issues, like environmental impacts of logistic restructuring, have been developed but with no quantification [39].

The first approaches to model, analyse and solve supply chain network equilibrium problems considered deterministic demand under profit maximization were proposed by Nagurney, Dong, and Zhang [40]. They analysed a super network perspective in which electronic commerce is also incorporated. Later on, Dong, Zhang, Hong and Nagurney [41] presented a model for the study of supply chain networks within multi criteria decisions, with the aim to maximize profit, minimize transportation time and maximize service level. Most of existing literature deals with configuring supply chains using cost minimization, service maximization [42], optimal inventory replenishment strategies and routing decisions under optimisation techniques [43, 44]. By addressing global network structures, business processes and management components [45] in and between companies, logistics can try to reduce total costs, reduce tied-up capital, increase customer service, reduce lead times and create more responsive and agile order-to-delivery processes. This study increases the understanding of potential alignment problems between logistics and legal issues, as asked for by Van Hoek, Ellinger and Johnson [46].

A similar problem to the one being presented, is the maximization of the worldwide after-tax net cash flow of a corporation, as discussed by Santoso, Goetschalckx,
Ahmed and Shapiro [47], where transportation cost allocations and duties are considered constant parameters; and on the inclusion of transfer prices in supply chain network optimal design in Goetschalckx, Carlos and Koray [48]. We also refer to Santos, Ahmed, Goetschalckx and Shapiro [49] that used sample average approximation method to compute solutions related with domestic and global network design. In a first stage they addressed costs minimization and in a second stage, for global network design, they explored after taxes profits maximization. Nevertheless, our approach differs from the large variety of decision support models and corresponding solutions for strategic design of supply chains, as there does not appear to exist a model using real options methodology, enhancing flexibility in the decision process, addressing simultaneously network design, logistic operations, inventory and transport costs, lead time, transfer prices, tax rates, in the choice of distribution points’ configuration under customer demand volatility.

3. REAL OPTIONS BACKGROUND

Real options are an important mechanism to measure the impact of risks in the decision process. The philosophy behind the concept reinforce the management ability in dealing with risk, making possible the transformation of potential threats into opportunities, or anticipating abandonment options to minimize undesired impacts.

In short, the application of real options approach relies on three main conditions, such as the existence of uncertainty, flexibility and irreversibility in the decision process.

Traditionally, one problem has been raised about real options methodology concerning the assumption about the irreversibility of costs to support the decisions. The application of this assumption tends to be discussed, mainly on resources that, due to the actual management evolutions and lean practices, are becoming more and more variable, which may violate the assumption about the irreversibility behind the application of resources within real options approach. Considering this reasoning, and to avoid that the assumption appears as a potential critical limitation to the application of real options methodology in the models we propose, we follow Henry [50] for whom, the irreversibility can be total or partial and can be seen as a limitation for the application of the resources within an extended period of time. This definition deserves a deep analysis. First irreversibility is not a closed concept; instead it can be used to explain that a present resource allocation cannot be fully recovered if the decision is reverted, because of future market conditions [51, 52, 53]. Second, the irreversibility normally can also be discussed in traditional techniques as it tends to create protectionism, by increasing the expected return, mainly under conditions of high uncertainty [50]. Third, the irreversibility allows the quantification of postponing decisions and the investment to a future moment, where new the information can add a better support on the decision process [54, 55]. Fourth, the irreversibility concept is more relevant to the decision process when traditional techniques (such as free discounted cash flow) present small payback values, which are highly dependent on future conditions. Such a situation reinforces that uncertainty is not a barrier in the decision process [52, 56]; which is also supported by Trigeorgis [57], for whom, an option gives the right to obtain future values, but not the obligation to assume potential losses.

4. MODEL

We present a model based on an integrated location and distribution centres, focused on a multinational corporation, with different subsidiaries and branches, incorporating tax rates as exogenous variables. We will assume that the multinational company has the ability to take decisions regarding its distribution network, under a corporate authority. The model considers a global distribution network consisting in a manufacturing facility, distribution centres and customer (retail) zones.

To support the model, we will make reference to the term “platform”. For a better understanding of the general application of the concept, the term distribution platform refers to a form to integrate the logistics processes and its activities, and the information systems, as homogenous part of the logistics system, in which a logistics organization centrally design, manage, report and control the logistic services [58]. It’s a specialised area with the infrastructure and services required for transportation, logistics and distribution of goods, where different agents can coordinate their activities to benefit the competitiveness of the products making use of the available infrastructures. Based on the above definition, we can distinguish between different types of distribution platform, according to their operative complexity and operational integration: uni modal distribution centres, are infrastructures operating as storage facilities largely aimed at the management of product flows and associated stocks; logistic areas, involving more integrated operations, with stock consolidation, local and redirectioning activities; finally, multimodal logistic platforms are logistic nodes connecting different modes of transport, emphasising added value services and not the specific transport modality used and are generally run by several operators.

Sets to support a general application for different distribution network designs:

- \( F = \{1, \ldots, N_f \} \) potential factories,
- \( I = \{1, \ldots, M_i \} \) potential distribution platforms,
- \( N = \{0, \ldots, N \} \) network combinations
- \( W = \{1, \ldots, W \} \) transportation alternatives available
- \( T = \{1, \ldots, T \} \) planning period under analysis

The objective of the problem is to configure the whole distribution network so that the corporate firm net bottom-line result is maximized under a stochastic market approach. Stochastic customer demand can be met from any distribution centre via different transportation modes and lead times. Depending on overstocking costs, different
is stochastic is the long term mean, \( \varepsilon \) is a serially uncorrelated and normally distributed random variable and \( \Phi \) is the jump size, with distribution \( dq \) (Poisson), for jumps occurrence. Jump size is modelled as a random variable. \( N(0,1) \) represents a standard normal distribution.

The demand estimation is calculated according equation (1):

\[
dD_i = \kappa(D - D_i)dt + \sigma \sqrt{dt} + \Phi \, dq
\]

Where: \( dq = \varepsilon(t)\sqrt{dt} : \varepsilon(t) \approx N(0,1) \). \( \kappa \) is the speed of reversion, \( D \) is the demand long term mean, \( \sigma \) is the volatility of the process; \( dw = \varepsilon(t) \) is increment of a wiener process; where \( \varepsilon(t) \) is a serially uncorrelated and normally distributed random variable and \( \Phi \) is the jump size, with distribution \( dq \) (Poisson), for jumps occurrence. Jump size is modelled as a random variable. \( N(0,1) \) represents a standard normal distribution.

The demand estimation is calculated according equation (1):

\[
D_i = D_{i-1} e^{-\alpha t_i} + \frac{\lambda}{\alpha} (1 - e^{-\alpha t_i}) + \sigma \sqrt{\frac{1 - e^{-2\alpha t_i}}{2\alpha}} N(0,1) + \text{jump size}
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It is expected that in a certain moment within planning period, \( T \), there will be a demand level, \( D_i \), at \( t \leq T \), that supports a network design change decision, considering the outcome results. To model our problem we will assume a different unit profit function, prior and after the decision, for the different network design decisions, which we will denote as \( \pi_n^u \), \( \pi_n^a \), respectively, with \( n \in N \).

Platform 1 to market (actual status: \( n = 0 \)):

\[
\pi_n^u(D_i) = \left( sp - c_i^p - h_q - c_i^{1,0} - \rho_u c_i^{1,0} - \chi_u \right) (1 - \chi_i^u)
\]

Equation (3) represents the profit function prior to any network alternative (alternatives: \( n \in N : n \neq 0 \)), considering direct deliveries from platform 1 (manufacturing point, network combination: \( n = 0 \)) to the market.

Distribution network combination: \( n \in N : n \neq 0 \):

\[
\pi_n^a(D_i) = \left( sp - c_i^p - h_q - c_i^{1,0} - \rho_u c_i^{1,0} - \chi_u \right) (1 - \chi_i^u)
\]

Equation (4) represents the profit function if the company uses the network alternative, considering deliveries using platforms \( i : i \in I \), included in the network design \( n : n \in N \).

Parameters used in the model:

\( h_q \), \( p^i \) and \( s^i \) represent, the handling, picking and warehousing costs for platform \( i : i \in I \) for each period of time;

\( c_i^f \) representing the unit production cost for factory \( f : f \in F \);

\( sp \) representing the unit CIF selling price;

\( \chi_i^u \) representing the tax rate for platform \( i : i \in I \);

\( \rho_u \), representing the unit CIF transfer price between platform \( i \) and \( j : i, j \in I : i \neq j \);

\( c_1^{1,0} \) and \( c_2^{1,0} \) represent the transportation cost using transportation \( w \) from platform \( i \) to the market and from platform \( i \) to platform \( j \), with \( i, j \in I : i \neq j \);

\( L_{i,0} \) and \( L_{i,j} \) represent the transportation lead time using transportation \( w \) from platform \( i \) to the market and from platform \( i \) to platform \( j \), with \( i, j \in I : i \neq j \);

\( r_u \) represents the required lead time for a sales delivery to be fulfilled.

The optimal network design is the one that maximizes the net profit under uncertain demand. \( \pi_n^u[D(t)] \) represents the actual profit using direct deliveries \( n = 0 \), when the company decides to change the network the net profit will be \( \pi_n^a[D(t)] \), with \( n \in N : n \neq 0 \) but to persevere the change there are irreversible costs related with the creation of new branches and regular running costs; customer retention (minimum contracted period) fees and penalties for contract termination with outsourced suppliers, in each platform, which will be denoted using \( \phi_n^u \) and \( \gamma_n^a \), respectively. The network design change value (NDCV), depends on the demand quantity and will the result from equation (5) that follows.

\[
\text{NDCV}(D_i) = \max \left( \pi_n^a[D_i] - \pi_n^u[D_i] - r_u - \phi_n^u - \gamma_n^a, n \in N \right)
\]

By solving equation (5), we find the optimal decision and its additional positive contribution to the net bottom-line profit of the company. It is also possible to find the trigger moment after which the decision should be taken.

5. PRATICAL IMPLICATIONS

Global business initiatives are a proven way to reduce operational costs and increase profits; however, without an adequate focus on taxes impact, these initiatives will fall short of their potential to drive shareholder value.

With regards to its practical implications, the presented study provides supply chain managers and decision makers with a useful tool for supporting the design of global logistics networks. By using this model, decision makers will be able to study different scenarios and therefore determine a more profitable logistics network configuration. At the end, the network design should be affected by relevant business drivers but also by after-tax profits.
6. LIMITATIONS AND FUTURE DEVELOPMENTS

Although not discussed in this article, the indirect tax issues should not be forgotten and indeed play an important part in determining the optimal tax-aligned distribution network. In general, the VAT should not be a true cost to business. However, there are situations, mainly outside Europe, when VAT is a net cost and therefore affect the profit and loss statement.

The organization's management incentives should also be considered to determine whether they lead to optimised decisions or not. Additional considerations may be given to whether these incentives can be aligned to achieve the optimised distribution network on an after-tax profit basis.

7. CONCLUSION

This research focused on distribution centres location issues in the context of global business. We developed a model based on various network configurations and tax rate levels. The model can support logistic strategies to help optimising decisions related to distribution centres while integrating tax implications, targeting the net bottom-line results optimisation.

A model that incorporates relevant factors impacting the firms’ net bottom-line results can be both meaningful and useful to managers, who can then use it in real world scenarios. The traditional cost factors used in network design decisions like handling, picking, transportation and warehousing, or time arguments like overstocking and transportation lead time can be complemented with financial topics concerning after-tax profits.

Efficient end-to-end tax distribution network management is now an actual concept that aims at avoiding that taxes lead to sub-optimal logistic models. Instead, taxes should be integrated into network and operating designs, avoiding tax obstacles to achieve business goals.

The integration of a distribution network design with an international tax overview increases shareholder value. By analysing the tax burden, any improvement from distribution network design will flow through to the bottom line. As so, the distribution network design changes can be implemented more efficiently.

The legal systems determine the playing ground rules for global companies when designing their supply chains. If chains are designed without taking this into consideration, tax consequences may arise that erase the efficiencies created by the logistic strategy.

The model illustrates the impact the tax system could have on distribution network design. That the logistics and fiscal systems interaction should be obvious, as for both domains how material flows is important: from where is it sourced, where value is added, to where is it distributed. When a company starts with optimising its global logistics structure, should also count with the interaction with after-tax impacts.

To bring about the full business and profit benefits of distribution models transformation, a holistic approach is critical to combine the distribution models and taxes. The master conclusion from this work is that the execution of a network strategy will therefore continue to be business driven, but it should be also tax aligned.

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