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Impact of taxation on international transfer pricing and offshoring decisions

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Abstract A multinational company may move production to a foreign country to take advantage of low manufacturing cost, and/or experience tax savings. Transfer prices play an important and strategic role on income shifting by multinational companies. In this paper, we construct a framework for optimal decision making in global supply chains with uncertain and price-dependent demand, propose methods to improve global supply chain parties' performance, and explore schemes to integrate global supply chains. The optimal pricing and offshoring decisions are investigated for different situations where the low foreign production cost and low foreign tax rate exist or only one of them is available. The case of low foreign tax rate without the advantage of low foreign production cost provides the most interesting findings that partial offshoring dominates when a certain threshold is met. In addition, the double marginalization is examined in decentralized global supply chains similar to the mechanism in newsvendor problems. Due to the existence of the tax jurisdiction, the double marginalization cannot be completely eliminated by coordinating schemes. Finally, the traditional buy back contract is found to be unable to coordinate global supply chains, while a modified sales sharing contract can improve the performance of the global supply chain.

Keywords Transfer price · Offshoring · Tax savings · Global supply chain integration

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1 Introduction

Offshoring of manufacturing operations has attracted attentions of managers and researchers in recent years. Multinational companies (MNCs) may have pure or mixed manufacturing modes when they make decision on offshoring. If companies move all manufacturing overseas, as done by Nike or Nokia, they do not have any domestic production. Other companies only partially offshore their manufacturing while keeping certain production local, as Toyota and Intel. The companies in the latter category follow the mixed production mode where their global decision-making is more complex. The strategies that those companies follow for mixed production mode are highly diverse. They may commit themselves to maintain a home country image, be restricted to the foreign capability of advanced technology, or be incented by government aids (e.g., Toyota 2011). In 2010, President Obama endorsed a proposal to give Intel a permanent \$100 billion tax credit to encourage it in its home manufacturing (Gravelle 2010).

Basically, the factor driving MNCs to offshore fully or partially is the low production cost in foreign countries such as China, India and Indonesia (Vidal and Goetschalckx 2001), moderated by increased shipping costs. The difference between domestic and international taxation is another basic factor (Hsu and Zhu 2011). The government incentive on tax credit works on the opposite way to attract companies to move production back home. This is now called "reshoring" (Davidson 2010). It reveals the impact of international taxation on global supply chain decisions. Companies, therefore, move production to a foreign county to experience cost savings, and/or take advantage of the difference in tax rates (Shunko et al. 2010), though global supply chain decisions on pricing, offshoring and others are affected by numerous other factors including trade barriers and tariffs, transportation cost, uncertain lead times, local laws, nation's currency etc. (Vidal and Goetschalckx 2001; Prasad and Sounderpandian 2003; Perron et al. 2010; Schnabel 2011).

Offshoring inevitably requires a bridge on shifting income when MNCs transport the production back to home country. It is the transfer price (Abdallah 1989). The existence of transfer prices changes the structure and policies on optimal decision-making in global supply chains. As indicated in the tax accounting literature, the differential national tax regimes motivate MNCs to engage in income shifting and after-tax profit improvement via the role of transfer prices. For example, a MNC experiences a low unit production cost of \$1 in her subsidiary in India and a retail price of \$10 in the American market. Let us assume that the corporate tax is .2 in India while .4 in America ignoring tariffs and any other tax related issues such as VAT. If the MNC sets up a transfer price at \$2, her total after-tax profit is $(\$2 - \$1) \times .8 + (\$10 - \$2) \times .6 = \$5.6$. However, if she sets the transfer price at \$9, her total after-tax profit increases to \$7 which implies a 25 % improvement. This simple example indicates that when an MNC takes into account low foreign production cost and low foreign tax rate as well, she will shift income from her foreign subsidiary and extract high benefit if the transfer price can be arbitrarily high. To avoid such intentional income shifting, national governments install intra-firm transfer pricing regulations and principles from a tax perspective (OECD 1979; Halperin and Srinishi 1987). In summary, there are three basic transfer pricing methods namely comparable uncontrolled price method, cost plus method and resale price method. All other methods are classified into the fourth method. More detailed information can be found in Halperin and Srinishi (1987).

Due to transfer prices involved, the optimal decision-making including pricing and purchasing in global supply chains radically differs from traditional newsvendor problems. Tax rate is not a crucial factor in a simple newsvendor problem with one manufacturer and one retailer. But it influences the decisions of MNCs considering the existence of after-tax profit.

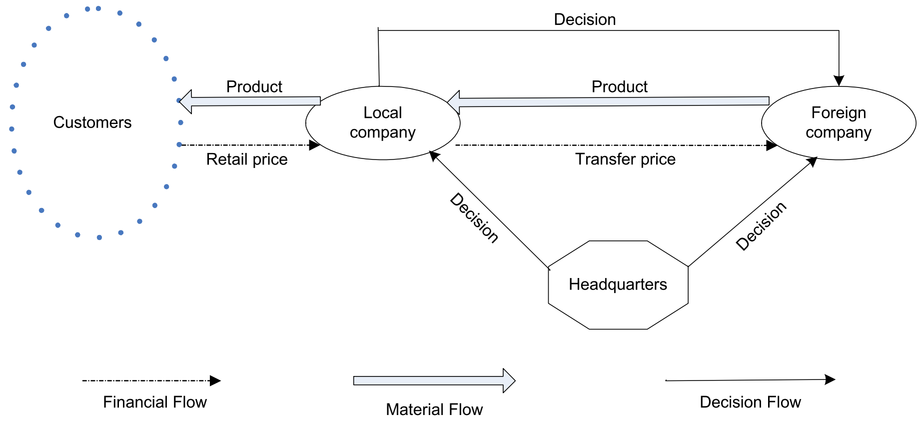

Fig. 1 The structure of global supply chains

At the same time, governments acting as the party collecting tax revenue, is also a part of the global supply chains, though governments perform invisible passive role while MNCs make optimal decisions on their pricing, purchasing, and offshoring as well. The role of governments on global supply chains has not been adequately studied in the operations literature. When offshoring exists, the local company can be considered as the retailer and he has a goal conflict with the headquaters (HD) who decides the transfer price. Such structure is similar to the traditional newsverdor problems. Therefore, double marginalization may exist. How to coordinate global supply chain becomes a new research subject which has not been attentively addressed in the literature.

In this paper, we first construct a framework for optimal decision making in global supply chains, study methods to improve global supply chain parties' performances, and then explore schemes to integrate global supply chains. Following the common demand structure in newsvendor problems, we assume uncertain demand is also price dependent (Petruzzi and Dada 1999). We perform the investigation by applying similar global supply chain structures used in Shunko and Gavirneni (2007) and Shunko et al. (2010). A general global supply chain structure is illustrated in Fig. 1. Our contributions will be more explicitly stated in Sect. 2 by reviewing the relevant literature.

The remainder of this paper is organized as follows: In Sect. 2, we review the related literature and state our paper's contribution. In Sect. 3, we establish the basic model framework and study the effect of tax rates on pricing strategy. In Sect. 4, we study optimal decision making in centralized and decentralized price-setting global supply chains, taking into account of the foreign production cost advantage and/or foreign tax advantage. Next, the global supply chain integration is explored in Sect. 5. We conclude the paper in Sect. 6 with managerial insights and further research.

2 Literature review

This research is relevant to several streams of literature: transfer pricing models in global supply chain, tax strategies in global supply chain modeling, inventory models with price dependent demands, and supply chain coordination contracts. We review each stream separately and state our contribution accordingly.

A large body of work in literature has focused on the role of transfer pricing in global supply chain since offshoring is considered as one of the competitive strategies of companies. Ernst & Young conducted a global transfer pricing survey in 2012 and observed that 74 % of parent companies and 76 % of subsidiaries believe that transfer pricing will be either "absolutely critical" or "very important" to their organizations over next two years (Ernst & Young 2010–2013). A number of papers on transfer pricing have been published from an accounting perspective (Hirshleifer 1956; Horst 1972). In the operations management literature, however, the importance of the transfer pricing in global supply chain design has not been studied extensively. In most existing global supply chain models, transfer prices are not considered as an explicit decision but as fixed and given instead (Meixell and Gargeya 2005). Few researchers mentioned that transfer prices may significantly affect MNCs' after-tax profit. They present mathematical models to optimize the global after tax profit with decision variables on the transfer price, the transportation cost allocation, marketing advertising, grey markets competition, the flow of goods and others (Nieckels 1976; Cohen et al. 1989; Arntzen et al. 1995; Vidal and Goetschalckx 2001; Goetschalckx et al. 2002; Perron et al. 2010; Erickson 2012; Autrey and Bova 2012). Most of those models are formulated as bilinear program or dynamic program and solved exactly or heuristically. No general analytic framework has been developed on the optimization of global supply chains with strategic transfer pricing. Our paper engages in proposing such analytic mechanism in global supply chains by paralleling the framework of single-period newsvendor problems.

Empirical research in accounting attributes offshoring decisions partly to tax savings that occur from the difference of tax rates (Mutti 2003). De Mooij and Ederveen (2003) performed a summary study of empirical research on foreign direct investment responsiveness to tax rates and found that on an average of 1 % reduction in a country's tax rate leads to 3.3 % increase in the country's foreign direct investment. This evidence suggests that low tax rate countries do attract more foreign companies. In operations management literature, however, the importance of taxation for offshoring has not been studied extensively. Usually the tax rates are fixed parameters in mathematic global supply chain models as we described in our literature review of transfer pricing. A couple of recent papers address the taxation strategy in global supply chains to pursue profit maximization. Bogataj and Bogataj (2011) consider free economic zones as a tool to hedge the fluctuation of logistics and skilled human resources. Their paper examines the level of reduction of tax burden in the free economic zones of accession countries. Hsu and Zhu (2011) study the impact of a set of China's export-oriented tax and tariff rules on the optimization of four major supply chain structures. The products are produced in China and sold in markets both inside and outside China. These small number of papers tactically discuss the role of taxation but without the transfer price involved. Our work attempts to combine the taxation and transfer pricing strategy, and investigate how the tax rates in different circumstance influence the decision of transfer prices and then the optimal decision making in global supply chains.

The literature on inventory models with price dependent demand is comprehensive. Most of the operations management literature dealing with pricing and inventory can be found in newsvendor-type models. Petruzzi and Dada (1999) provide an intensive review of single-period problems, while Federgruen and Heching (1999) and Chen and Krass (2001) review the multi-period models. Inventory models with dynamic pricing are also investigated in recent literature. Song et al. (2009) study the optimal dynamic decision making problem in a price-setting multiplicative demand framework by incorporating lost sales, holding cost and salvage values. Feng (2010) examines the value of dynamic pricing in the presence of supply capacity uncertainty and states that the base-stock list-price policy fails to optimize the supply chain performance. Shunko et al. (2010) study an additive demand structure on global supply chain with all deterministic parameters. Our work differs from their work by applying the demand structure in global supply chain under uncertain circumstances where the pricing is additionally influenced by the transfer price and offshoring decision.

Extensive work in literature addresses issues of supplier-buyer coordination. Readers are referred to Cachon (2003) for a general review of single period, where a number of traditional contracts including buy back, sales rebate, quantity flexibility, revenue sharing and others are discussed and compared. Song et al. (2008) provide an intensive study of a buy back contract for price-setting newsvendors. A few papers on coordination mechanism can be found in global supply chain literature. Kouvelis and Gutierrez (1997) examine optimal control policies for a two market stochastic inventory system in a global market. Souza et al. (2004) study the firm's optimal response to a supplier's one-time price discount for a critical component. Bhatnagar et al. (2011) address the problem of coordinating aggregate planning decisions and short-term scheduling decisions in supply chains with dual supply modes. The common point among these papers is that the word "global" means *diverse* supply and/or demand (markets). The transfer price has not been addressed in global supply chain coordination and the study of governments' role and benefit via taxation on global supply chains is left blank. Leng and Parlar (2012) construct a cooperative game to allocate the chain profit between divisions and determine the Shapley value-based transfer price. Our paper focuses on filling the blank by exploring global supply chain coordination contracts taking into account the impact of transfer pricing from a more general perspective.

3 The base model—the effect of tax rates

We consider a product that faces price-sensitive uncertain demand in the local market. Considering the multiplicative demand form has been widely used in the production-price decision literature (such as Petruzzi and Dada 1999; Cachon and Kok 2007; Wang 2006), we assume the demand to be multiplicative given as $D(P) = y(P)\varepsilon$ where $y(P) = aP^{-b}$. P is the retail price, b is the price-elasticity index of demand, and a is the market size. If the price-elasticity index b is greater than 1, products are defined as being price-elastic; otherwise it is inelastic. We focus on price-elastic products and thus assume that $b > 1$. In addition, $a > 0$ is assumed to make the demand non-trivial. To capture the uncertainty in market demand resulting from changes in economic and business conditions, we assume that ε is a random factor with CDF $\Phi(\cdot)$, PDF $\phi(\cdot)$, and the expected value $\mu = E\varepsilon$. Assume that the probability distribution has support on $[A, B]$ with $B > A \geq 0$. Let q denote the production, we define $z = \frac{q}{y(P)}$, and call it the stocking factor of inventory (following Petruzzi and Dada 1999).

To pursue the manufacturing cost advantage, low labor cost and other managerial expense, we assume the MNC moves all production to the subsidiary located in foreign country F. The MNC does not possess any factory or production center in local company L. This is our base model providing basic results. Later, we will present our general model in the next section. A transfer price T per unit is paid by the local company to the foreign subsidiary. The manufacturing cost in the foreign country is c_F. t_L and t_F are tax rates in the local and foreign countries, respectively. For the purpose of simplicity, we assume that any unsold product at the end of the season bears no salvage value or disposal cost. In addition, we assume that unsatisfied demand carries no additional penalty (shortage cost) except for the loss of sales revenue. For seasonal or short life-cycle products, zero salvage value or holding cost and zero shortage penalty assumptions are appropriate reflections of reality.

Given the transfer price T, the expected profit in the local country L before tax is:

$$\begin{aligned}\pi_L &= PE\big[\min\{q, D\}\big] - Tq \\ &= Py(P)E\big[\min\{z, \varepsilon\}\big] - Tzy(P) \\ &= y(P)z(P - T) - Py(P)\Lambda(z) \qquad (1)\end{aligned}$$

where $\Lambda(z) = \int_A^z (z - x)\phi(x)dx$ and $y(P)\Lambda(z)$ represents expected leftovers.

The expected profit in the foreign country F before tax is:

$$\pi_F = (T - c_F)q = y(P)z(T - c_F) \qquad (2)$$

Total supply chain's profit after tax is:

$$\pi = \pi_L(1 - t_L) + \pi_F(1 - t_F) \qquad (3)$$

We will look at different global supply chain designs where the retail price is decided by different parties, while the transfer pricing decision is always centrally made by the HD. The subsequent analysis will demonstrate the role of different design structures on the optimal decisions including the transfer pricing in global supply chains.

As we mentioned in the Introduction, there are several different legal methods of calculating intra-firm transfer price. Baldenius et al. (2004) proposed a range of allowable arm's length prices given cost-based transfer pricing. Following their format, in this paper, we set up T_U as the upper limit of transfer prices, and require T_U higher than the production cost c_F. In addition, to compromise most common accounting rules, i.e., transfer prices should not be lower than the production cost or higher than the retail price P. In summary we restrict transfer prices to a reasonable range $c_F \le T \le \min\{T_U, P\}$.

3.1 Centralized pricing decision

In this scenario, the retail price is made centrally, i.e., both the transfer price and retail price are set up by the HD. This scenario is likely to occur when the local company only acts as a sales division of the MNC and has little negotiation power. We solve the following maximization problem:

$$\begin{aligned} &\max_{P,T,z} \quad \pi \\ &\text{s.t.} \quad c_F \le T \le P \end{aligned} \qquad \text{(P1)}$$

Proof of most theorems and propositions are given in the Appendix.

Theorem 1 *If $b \ge 2$ and $\Phi(\cdot)$ has an increasing failure rate over the region $A \le z \le B$, the optimal solutions for the centralized model are*

(a) *If $t_L > t_F$, $T_c^* = \min\{T_U, T_{L+}\}$, $P_c^* = K^*M^*$, where*

$$T_{L+} = \frac{bc_F(1 - t_F)}{b(1 - t_F) - (1 - t_L)}, \qquad M^* = \frac{(1 - t_L)T_c^* - (1 - t_F)(T_c^* - c_F)}{1 - t_L} \quad \text{and}$$

$$K^* = \frac{bz_c^*}{(b - 1)(z_c^* - \Lambda(z_c^*))}$$

(b) *If* $t_L < t_F$, $T_c^* = c_F$, $P_c^* = \frac{bz_c^* c_F}{(b-1)(z_c^* - \Lambda(z_c^*))}$,

where z_c^* *in both* (a) *and* (b) *satisfies* $\Phi(z_c^*) = \frac{z_c^* + (b-1)\Lambda(z_c^*)}{bz_c^*}$.

Note that $b \geq 2$ is not a necessary condition for optimal solutions. We place such condition here to make the analytical solutions tractable. We will resort to numerical solutions for other conditions. Comparing the retail prices in the two cases, it can be seen that P_c^* is lower when $t_L > t_F$. So the tax rates do play a role on pricing decisions. We will show that, in decentralized global supply chains, optimal retail price cannot be freely set due to the parties' conflicting goals. This is similar to the double marginalization in single newsvendor problems.

Corollary 1 *The market enjoys the advantage of a lower retail price if there exists a foreign tax benefit.*

Proof $M^* = \frac{(1-t_L)T_c^* - (1-t_F)(T_c^* - c_F)}{1-t_L} < c_F$. And without a tax benefit, the retail price would be $P_c^* = \frac{bz_c^* c_F}{(b-1)(z_c^* - \Lambda(z_c^*))}$. □

The notation T_{L+} in Theorem 1 represents a limit below which a nonnegative local profit is guaranteed. We can prove that $T_{L+} = \frac{b(1-t_F)c_F}{b(1-t_F)-(t_L-t_F)} < 2c_F$ when $b \geq 2$ and $t_L > t_F$. Therefore, if the transfer price ceiling T_U is larger than twice the foreign production cost, $2c_F$, the HD will set up a retail price to breakeven local company's profit and ensure the global chain squeezes all the tax revenue.

In addition, we mentioned $T_{\leq P}$ in the proof of Theorem 1. $T_{\leq P}$ there denotes a threshold below which the condition $T \leq P$ is satisfied. The following corollary shows that the optimal retail price under centralization is always strictly greater than the transfer price, which cannot be taken for granted in other decentralized scenarios to be discussed in following sections. That is also why we do not include the $T_{\leq P}$ in the criterion of the optimal transfer price.

Corollary 2 *If* $b > 1$, *then* $T_{L+} < T_{\leq P}$, *where*

$$T_{L+} = \frac{bc_F(1-t_F)}{b(1-t_F)-(1-t_L)} \quad \text{and} \quad T_{\leq P} = \frac{K^* c_F(1-t_F)}{K^*(t_L-t_F)+(1-t_L)}.$$

Proof Since $(b-1)\Lambda(z_c^*) > 0$ if $b > 1$, we have $\frac{1}{b} < 1 - \frac{1}{K^*}$, and thus $T_{L+} < T_{\leq P}$. □

The centralized pricing model offers the first-best solution for the MNC if we assume that all the products are made overseas.

3.2 Decentralized pricing decision by the local company

In this scenario, the local company has the power to independently decide the pricing strategy due to his acquaintance of the local market. Also, to pursue higher demand and larger market share, the HD would find it helpful to leave the pricing decision to the local company and then motivate him to put more efforts in sales.

Under such circumstances, the retail price is decided by the local company acting as a retailer, while the transfer price is still set up centrally. It can be considered as a Stackelberg game, where the HD acts as the leader, and the retailer is the follower. We solve the following maximization problem:

$$\begin{aligned} \max_{T} \quad & \pi \\ \text{s.t.} \quad & c_F \le T \le P \\ & P, z \in \arg\max_{P,z} \pi_L \end{aligned} \tag{P2}$$

Proposition 1 (the retailer's optimal decision given T) *For any fixed z such that $A \le z \le B$ and feasible transfer price T, the unique optimal price P_d^* is given by $P_d^*(z) = \frac{bzT}{(b-1)[z-\Lambda(z)]}$. In addition, if $b \ge 2$ and the probability distribution $\Phi(\cdot)$ has an increasing failure rate, the optimal z_d^* is uniquely determined by $\Phi(z_d^*) = \frac{z_d^*+(b-1)\Lambda(z_d^*)}{bz_d^*}$.*

Proposition 1 indicates that the pricing decision of the local company is mostly built on the transfer price and the characteristic of demand uncertainty. The foreign tax advantage is out of consideration. Since $bz > (b-1)[z-\Lambda(z)]$, the local company always sets a retail price much larger than the transfer price to achieve a profit margin as high as possible.

The first-best solution in Theorem 1 suggests that the HD sets up a high enough transfer price to absorb all the legal tax burden with breaking even the local profit. The following Proposition 2 shows that there is always a positive profit obtained by the local company. In other words, the tax revenue is shared with the local government. The deviation of the retail price in such decentralized case inevitably leads to a sub-optimal profit. Interestingly, this deviation becomes smaller as the price-elasticity b increases, which can be observed from the proof in Proposition 2. The HD may then use the decentralized pricing strategy on those products in highly competitive market to acquire local company's sales effort, but not sacrifice the channel profit too much.

Proposition 2 *If the retail price has the form as $P = \frac{bz}{(b-1)(z-\Lambda(z))}T$, the local company must have a positive profit, where T is any eligible value.*

Proof

$$\begin{aligned} \pi_L &= y_P z(P-T) - y_P P\Lambda(z) = y_P T\left\{z\frac{bz-(b-1)(z-\Lambda(z))}{(b-1)(z-\Lambda(z))} - \frac{bz\Lambda(z)}{(b-1)(z-\Lambda(z))}\right\} \\ &= \frac{1}{b-1} y_P z T > 0 \end{aligned}$$

□

Given the results in Proposition 1, we present the optimal solutions and other findings of the programming (P2).

Theorem 2 *If $b \ge 2$ and the distribution $\Phi(\cdot)$ has an increasing failure rate, the optimal transfer price is shown as follows:*

(a) *If $t_L > t_F$, $T_d^* = \min\{T_U, T_D\}$, $P_d^*(z_d^*) = \frac{bz_d^* T_d^*}{(b-1)(z_d^*-\Lambda(z_d^*))}$, where $T_D = \frac{bc_F(1-t_F)}{b(1-t_F)-(t_L-t_F)}$;*

(b) *If $t_L < t_F$, $T_c^* = c_F$, $P_d^* = \frac{bz_d^* c_F}{(b-1)(z_d^*-\Lambda(z_d^*))}$, where z_d^* in both* (a) *and* (b) *satisfies $\Phi(z_d^*) = \frac{z_d^*+(b-1)\Lambda(z_d^*)}{bz_d^*}$.*

First of all, when we compare the optimal solutions in Theorems 1 and 2, we see that they are exactly consistent when the foreign tax benefit is not present. The HD has to set up a low enough transfer price c_F to the local company, and he has no motivation to make an inflated retail price. However, if $t_L > t_F$, the HD has to set up a low transfer price to reduce the effect on the market of an inflated retail price. Unfortunately, such negative effect cannot be completely eliminated. We will discuss in detail about the integration of global supply chain in Sect. 5.

Corollary 3 *If* $0 < t_L, t_F < 50\ \%$, *the transfer price satisfies* $T_d^* < T_c^*$ *with a corresponding higher retail price in decentralized global supply chain, i.e.* $P_d^* > P_c^*$.

Proof According to previous discussion, in most cases, we may assume $T_c^* = T_{L+}$ and $T_d^* = T_D$. Given a reasonable range of taxes, $0 < t_L, t_F < 50\ \%$, we can prove $T_D < T_{L+}$. $P_d^* > P_c^*$ can be verified by $T_D > c_F$. □

A low transfer price restricts the HD from extracting the whole foreign tax benefit; and also the higher retail price brings the MNC a smaller pie of the market. Even without further deduction, we can conclude that the global supply chain profit is lower than the best solution. The findings here remind us the effect of double marginalization in simple newsvendor problems. But in newsvendor problems the manufacturer charges the retailer a wholesale cost higher than her production cost, while in global supply chains, the transfer price in the decentralization case is lower than that in the centralization case. If we consider the wholesale price as one type of transfer price, the effect of taxes is then highlighted on the double marginalization and supply chain profit as well.

Another interesting finding on both centralized and decentralized global supply chains is that the HD keeps the transfer price fixed regardless of the characteristics of demand uncertainty. Only the model parameters, including the foreign manufacturing cost and tax rates in both countries influence the decision on the transfer price. It is most likely due to the transfer price's ceiling limit T_U and the requirement of non-negative local profit, which restricts the arbitrary change of the transfer price.

4 Offshoring and Transfer Pricing Strategies

The global supply chain decisions are influenced by numerous factors including cost savings, tax advantages, fluctuating exchange rates, transportation issues, and even country conditions, e.g., endowment factors, cultural variations, arbitrage and leverage opportunities, government incentives and regulations (Prasad and Sounderpandian 2003). To acquire competitive advantages, the HD needs to examine its activities in relation to the comparative advantages offered by various nations. The questions of how to offshore production and how much of production to be moved overseas should be carefully examined. Intuitively, if the foreign company has the manufacturing cost advantage and a low tax rate as well, offshoring all the production will undoubtedly benefit the MNC without considering other managerial factors. However, if the foreign company does not offer a lower manufacturing cost, but possesses a lower sales tax, then what will be the best decision? As we already know in the base model discussed in Sect. 3, the transfer price is one of the key factors in global supply chain management. The structure of transfer price here will again affect the channel performance.

Table 1 Four alternative global supply chain designs

		Pricing	
		Centralized	Decentralized
Offshoring	Centralized	$\max_{T,P,\lambda,z} \pi$	$\max_{T,\lambda} \pi$ s.t. $P, z \in \arg\max_{P,z} \pi_L$
	Decentralized	$\max_{T,P,z} \pi$ s.t. $\lambda \in \arg\max_{\lambda} \pi_L$	$\max_{T} \pi$ s.t. $P, z, \lambda \in \arg\max_{P,z,\lambda} \pi_L$

In this section, we restrict the factors under consideration that affect the global supply chain design to be the tax rates and manufacturing costs only, which is common in the literature especially in the accounting field. As we discussed in the Introduction, a few papers in the operations management area have intensively studied the transfer price and tax issues simultaneously. Therefore, we consider our assumption reasonable and also applicable. We assume that the MNC moves a proportion of production λ to the foreign country where it may experience cost or tax advantage, while keeping the remaining proportion $1 - \lambda$ to beproduced in the local country. $\lambda = 1$ means all the production is manufactured overseas, while $\lambda = 0$ indicates the global supply chain reduces to a local supply chain. We use all the assumptions applied in Sect. 3 except that the decision maker now need to control how much production should be moved to a foreign country. This decision of offshoring makes the analysis of the problem much more complicated.

Given the transfer price T, the expected before tax profit in the local country L is:

$$\pi_L = y(P)z\big(P - \lambda T - (1 - \lambda)c_L\big) - Py(P)\Lambda(z) \tag{4}$$

The expected before tax profit in the foreign country F is:

$$\pi_F = y(P)z\lambda(T - c_F) \tag{5}$$

Total supply chain profit after tax is:

$$\pi = \pi_L(1 - t_L) + \pi_F(1 - t_F) \tag{6}$$

In the following sub-sections, the discussion of global supply chain design will be based on the factors under consideration (tax rate and production cost), and the pricing and manufacturing strategies are set up by different parties. To be more specific, we have four alternative global supply chain designs (see Table 1) for different types of MNCs. The subsequent analysis will demonstrate how different design structures of global supply chains affect the decision makers on pricing via the transfer price as a lever and the tax rate as an adjustor.

4.1 Centralized all decisions

Although centralized model is hard to be realized in practice, it offers the first-best solution for the global supply chain. We will compare this case with other decentralized ones, study the variability of channel performances, and further establish applicable contracts or schemes to coordinate the global supply chain. We use the following formulation to explain such scenario:

$$\begin{aligned} &\max_{T,P,\lambda,z} \ \pi \\ &\text{s.t.} \quad \lambda \in [0,1] \\ &\qquad\quad c_F \le T \le P \end{aligned} \tag{P3}$$

Theorem 3 *If $b \ge 2$ and the probability distribution has IFR (increasing failure rate), the optimal solutions are as follows*:

(1a) *If $t_L > t_F$ and $c_L > c_F$, the optimal solutions are same as Theorem 1*(a);

(1b) *If $t_L > t_F$ and $c_L < c_F$, there exists an optimal $\lambda^* \le 1$ when the conditions $\{T_U, K^* c_L\} > \frac{c_F(1-t_F)-(1-t_L)c_L}{t_L-t_F}$ and $K^*b - (K^* + b) \ge 0$ are satisfied, then the optimal transfer price is $T^* = \frac{(1-\lambda^*)(1-t_L)c_L + \lambda^* b c_F(1-t_F)}{\lambda^*[b(1-t_F)-(t_L-t_F)]}$; Otherwise, if any of those two conditions is not satisfied, then no offshoring occurs.*

(2a) *If $t_L < t_F$ and $c_L > c_F$, the optimal solutions are same as Theorem 1*(b);

(2b) *If $t_L < t_F$ and $c_L < c_F$, no offshoring occurs.*

(1a), (2a) and (2b) in Theorem 3 are straightforward taking into account the consistency of the base model in Sect. 3. But surprisingly, it does not simply indicate either all or no offshore when only the foreign tax benefit exists. The MNC is motivated to offshore if the foreign tax benefit dominates the production cost loss, while keeps domestic production when the foreign tax benefit does not dominate over the advantage of a lower local production cost. Under the former situation, $\lambda = 1$ could bring the global chain with a better profit than that without offshoring. However, it might not be the best one due to the effect of the criterion required for the transfer price. The mixed production modes allow the MNC to gather both benefits from the lower local production cost and lower foreign tax.

If we look at the conditions required by offshoring in case (1b), $Q = \frac{c_F(1-t_F)-(1-t_L)c_L}{t_L-t_F}$ can be considered as the threshold of the transfer price for a MNC who pursues a profitable offshoring. If the eligible transfer price cannot exceed the threshold Q, it will fall into the latter situation discussed in the last paragraph. Another condition $K^*b - (K^* + b) \ge 0$ prevents the corporation overproducing oversea ($\lambda > 1$). The structure of Q also reveals how the global supply chain can benefit from offshoring.

Corollary 4 *The MNC is more likely to benefit from offshoring or a mix production mode when*

(1) *c_F becomes lower*; *or*

(2) *t_F becomes higher.*

Proof of Corollary 4 is direct. Numerical sensitivity analysis will be discussed in Sect. 4.2 along with the supply chain performance comparison among centralization and different decentralizations.

The detailed proof of case (1b) shows that the optimal offshore production λ^* is dependent on the characteristics of demand uncertainty. Accordingly, the transfer price is based on the uncertainty of demand, which distinguishes from the base model where only tax rates are considered. The influence of supply chain parameters on the optimal offshore proportion will be illustrated again in the following section.

4.2 Decentralized pricing decision by the local company

The centralized model always offers the best outcome under ideal conditions. It applies to the MNCs with the HD paramount to all child companies. In this section and following ones, we will discuss different decentralized models of the global supply chain.

Considering that the local company is much closer to the customer and has more information on demand, the HD delegates the power of retail pricing decision to the local company, while holding the offshoring decision. In this scenario, the HD acts as a leader, while the local company as a follower. The HD decides if the production is to be moved overseas and how much should be moved, and also sets up a transfer price to the local company. Then given the transfer price, the local company establishes a retail price to the customers. If all the production is done overseas, the local company can be considered as a retailer of the MNC. We describe the decision making structure as follows:

$$\begin{aligned} \max_{T,\lambda} \quad & \pi \\ \text{s.t.} \quad & P, z \in \arg\max_{P,z} \pi_L \\ & \lambda \in [0,1] \\ & c_F \le T \le P \end{aligned} \tag{P4}$$

Proposition 3 *For any fixed z such that $A \le z \le B$, the unique optimal price P^*_{cd} is given by $P^*_{cd}(z) = \frac{bz(\lambda T + (1-\lambda)c_L)}{(b-1)[z - \Lambda(z)]}$. In addition, if $b \ge 2$ and the probability distribution $\Phi(\cdot)$ has the IFR (increasing failure rate), the unique optimal z^*_{cd} satisfies $\Phi(z^*_{cd}) = \frac{z^*_{cd} + (b-1)\Lambda(z^*_{cd})}{bz^*_{cd}}$.*

Proof Directly follows from Proposition 1. □

Note that the HD maximizes her expected profit with respect to T and λ, based on the knowledge of local company's price decision. We summarize the optimal solutions in Theorem 4.

Theorem 4 *If $b \ge 2$ and the probability distribution $\Phi(\cdot)$ has increasing failure rate, the headquarters will make the following optimal decisions of T and λ based on the local company's decisions as in Proposition 3:*

(1a) *If $t_L > t_F$ and $c_L > c_F$, the optimal solutions are same as Theorem 2*(a);
(1b) *If $t_L > t_F$ and $c_L < c_F$, there exists an optimal offshore proportion $\lambda^* \le 1$ if $\{T_U, K^* c_L\} > \frac{c_F(1-t_F)-(1-t_L)c_L}{t_L - t_F}$; otherwise, no offshoring occurs.*
(2a) *If $t_L < t_F$ and $c_L > c_F$, the optimal solutions are same as Theorem 2*(b);
(2b) *If $t_L < t_F$ and $c_L < c_F$, no offshoring occurs.*

Discussion 1 *The result in case* (1b) *is not as clear as that in the centralization Theorem 3,* (1b) *due to the complication associated with the retail price decentralization, such as the effect of constraints, especially $T \le P$. Still, we derive closed form solution for most common parameters.*

To be more specific, the highest legal profit could be achieved by comparing $\pi_1(T^*, \lambda(T^*))$ and $\pi_2(\lambda^*, T(\lambda^*))$ from Path A and Path B discussed in the proof of Theorem 4(1b), *and the larger of them is makes the optimum. The formulas to obtain their values are as follows,*

$$T^* = \frac{-\hat{b} + \sqrt{\hat{b}^2 - 4\hat{a}\hat{c}}}{2\hat{a}},$$

$$\lambda(T^*) = \frac{c_L[(1-t_F)(T^*-c_F)-(1-t_L)(T^*-c_L)]}{(T^*-c_L)[(b-1)(1-t_F)(T^*-c_F)+(1-t_L)(T^*-c_L)]},$$

while

$$\lambda^* = \frac{-\tilde{b}+\sqrt{\tilde{b}^2-4\tilde{a}\tilde{c}}}{2\tilde{a}}, \qquad T(\lambda^*) = \frac{\lambda^* b c_F(1-t_F)-(1-\lambda^*)c_L(t_F-t_L)}{\lambda^*[b(1-t_F)-(t_L-t_F)]}$$

Where

$$\hat{a} = b(1-t_F)-(t_L-t_F),$$

$$\hat{b} = -b(1-t_F)c_F - b(1-t_F)Kc_L - \big(c_L(1-t_L)-(1-t_F)c_F\big),$$

$$\hat{c} = bKc_L(1-t_F)c_F; \quad \textit{and}$$

$$\tilde{a} = Kb(1-t_F)(c_F-c_L), \qquad \tilde{b} = c_L(t_L-t_F)+b(1-t_F)(Kc_L-c_F),$$

$$\tilde{c} = c_L(t_F-t_L)$$

Relevant proofs are shown in the Appendix.

Two possible optimal paths exist because of the ambiguous relationship between the total supply chain profit and the transfer price. Under centralization, however, when the threshold Q is met, the total supply chain profit increases as the transfer price increases, and then we have a clean proof there. As we discussed in the decentralized base model with foreign tax benefit, the HD usually has to set up a lower transfer price than the best one to assist the local company to have a good retail price. However, intuitively, a higher transfer price surely dominates given the foreign tax benefit in the centralization. Therefore the deviation from the best solution introduces the complication to the decentralized pricing model.

Considering that the decisions are much more interesting albeit more complicated when only foreign tax advantage exists, we illustrate the sensitivity analyses in the following figures only for this situation. The demand uncertainty is captured by ε, which is assumed to follow a uniform distribution on [1, 2]. This assumption satisfies the distribution requirement in all previous theorems. The price elasticity b is also carefully identified to meet the theorem conditions and then ensure the existence of analytic solutions. It is worth mentioning here that even if these conditions are not valid, we can use enumeration or heuristic methods to find the local optimum. In all of the following figures, the blue line shows the performance of the retail price under decentralization, the red one line those without any offshoring, and the green line for centralization.

The left chart in Fig. 2 shows us the change of the optimal retail price with respect to the local production cost, while the right one represents the global supply chain profit improvement from offshoring either under centralization or decentralization. The right one is much more intuitive, but interestingly, the profit improvement coming from decentralization is much smaller than that from centralization, i.e., the best solution. Even when the local production cost $c_L(=1.58)$ is close to c_F, i.e., the tax benefit clearly dominates, there is only about 5 % profit improvement. Such findings motivate us to think of the global supply chain integration. Detailed discussion will be presented in Sect. 5.

The left figure reflects the trend of the retail price with the change of the local production cost. There is no transfer price issue without offshoring, so the local company and the HD acts as the same entity. But the difference between no offshoring and decentralization where the local company decides the retail price is that the relative purchasing costs are different. To be specific, the unit purchasing cost is c_L without offshoring, while it is a weighted

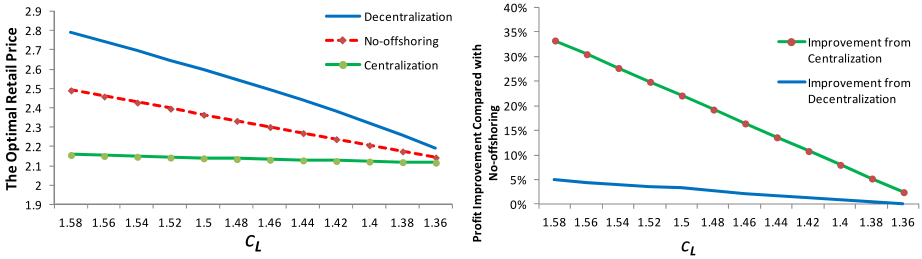

Fig. 2 Sensitivity analysis of local production cost on channel performance ($b = 3$, $c_F = 1.6$, $t_F = 0.1$, $t_L = 0.4$)

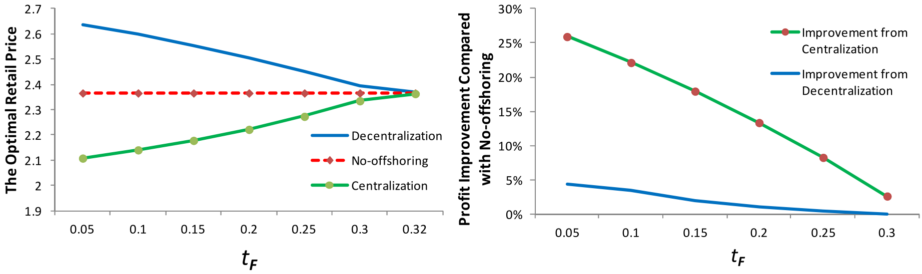

Fig. 3 Sensitivity analysis of foreign tax rate on channel performance ($b = 3$, $c_F = 1.6$, $c_L = 1.5$, $t_L = 0.4$)

mean between c_L and the transfer price $T (\geq c_F)$ under decentralization. Taking into account $c_L < c_F$, the unit purchasing cost under decentralization must be higher than that without offshoring. It explains why the optimal retail price under decentralization deviates more than that without offshoring. Note that both deviations can be explained by the previous discussion of the global double marginalization.

Figures 3 and 4 illustrate sensitivity analyses involving foreign tax rates c_F and price elasticity b. The graphs on the right show a trend similar to Fig. 2. We will explore the global supply chain integration in Sect. 5. When the foreign tax benefit gradually fades out, the retail price under centralization becomes higher and reaches the same level as in without offshoring, while the retail price under decentralization becomes smaller and meets the central line. The reason behind this phenomena is the change of the offshoring proportion λ with respect to foreign tax benefit (see Fig. 5). The lines for decentralized in Fig. 5 show predictable results. However, the pattern of centralization lines is counter to expectation. When the foreign tax benefit becomes smaller, but the offshoring proportion λ gets slightly higher, it would surely lead to a higher purchasing cost. Recall that most cases under centralization sacrifice the local company's profit to allow the market a low retail price which brings more demand to the global supply chain. That's why a positive λ is more competitive. When the foreign tax benefit is almost gone ($c_L \to 1.34$ or $t_F \to 0.35$), we verify that a positive λ provides a close supply chain profit with no offshoring. In such extreme cases, no offshoring might be better due to its simplicity.

One more interesting finding is the relationship between the optimal retail price and the transfer price. Given all the model parameters assumed above, the optimal retail price is always equal to the transfer price under both centralization and decentralization. Note that the global supply chain usually does not have full offshoring when only foreign tax benefit exists. Therefore, even the retail price equals the transfer price, the nonnegativity of the

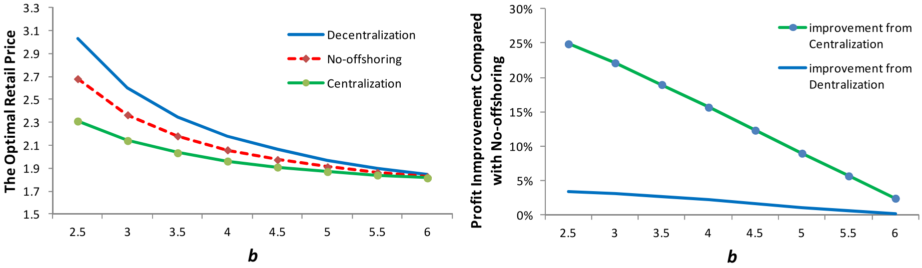

Fig. 4 Sensitivity analysis of price elasticity on channel performance ($c_L = 1.5$, $c_F = 1.6$, $t_F = 0.1$, $t_L = 0.4$)

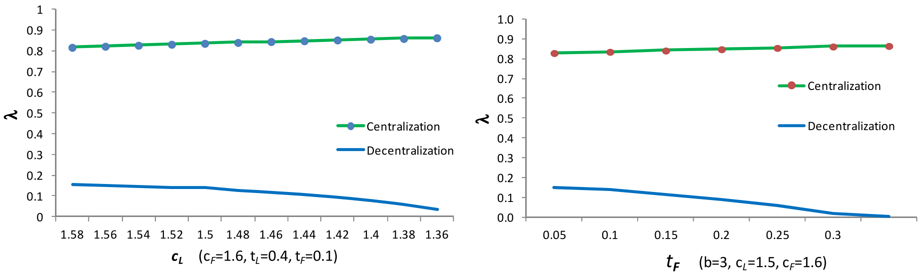

Fig. 5 Variation of offshoring proportion with foreign tax benefit

local profit is still guaranteed. Indeed, the local company takes the majority of the total global chain profit under decentralization.

4.3 Decentralized Offshoring Decision by the Local Company

Different from Sect. 4.2, in this scenario, the local company decides whether to move the production overseas or not, while the HD holds the pricing strategy. Such case generally appears when the local company has more information about the manufacturing cost, and is unlikely to share such information with the headquarters. We describe the decision making structure as follows:

$$\begin{aligned} \max_{T,P,z} \quad & \pi \\ \text{s.t.} \quad & \lambda \in \arg\max_{\lambda} \pi_L \\ & \lambda \in [0,1] \\ & c_F \le T \le P \end{aligned} \tag{P5}$$

Theorem 5 *If $b \ge 2$ and the probability distribution $\Phi(\cdot)$ has the IFR (increasing failure rate), the optimal solution is as follows:*

(1) *If $c_L < c_F$, no offshoring occurs;*
(2a) *If $t_L > t_F$ and $c_L > c_F$, when $c_L > \min\{T_U, T_{L+}\}$, the optimal solutions are same as Theorem 1(a); when $c_L \le \min\{T_U, T_{L+}\}$, no offshoring occurs.*
(2b) *If $t_L < t_F$ and $c_L > c_F$, the optimal solutions are same as Theorem 1(b).*

The interesting finding regarding the offshoring decentralization is that it ignores the foreign tax benefit unless the local production cost is extremely high, say $c_L > \min\{T_U, T_{L+}\}$. If the local company believes that the HD will issue a transfer price T lower than c_L, even as large as $c_L - \varepsilon$, where ε is a small number, he will agree with offshoring. Unfortunately, the HD's decision on T is difficult. On the other hand, the offshoring decentralization usually occurs when the local company has more information about the local production cost, and is unlikely to share such information with the HD. Thus the HD does not possess the true value of c_L, which makes it hard to set up a credibly low transfer price between the HD and local company. There might be two ways to solve such problem. One is to request information sharing between two parties, and the scheme of profit allocation should be set up in the meantime. The other way is the HD builds an incentive scheme and forces the local company to reveal the true information of his production cost and then a better global chain performance can be achieved.

4.4 Decentralized offshoring and pricing decision to the local company

When the local company has enough power, the HD may leave him with both the pricing and offshoring decisions. To achieve the maximum private benefit, in such case, the local company will set a high retail price and also a profitable offshore proportion. Intuitively, however, the global supply chain will perform the worst in all these four scenarios, though the local company may garner more profit compared with others. The optimal solutions can be constructed by the following formulation:

$$\begin{aligned} \max_{T} \quad & \pi \\ \text{s.t.} \quad & P, z, \lambda \in \arg\max_{P,z,\lambda} \pi_L \\ & \lambda \in [0, 1] \\ & c_F \le T \le P \end{aligned} \tag{P6}$$

Theorem 6 *If $b \ge 2$ and the probability distribution has the IFR (increasing failure rate), the optimal solution is as follows:*

(1) *If $c_L < c_F$, no offshoring occurs;*
(2a) *If $t_L > t_F$ and $c_L > c_F$, when $c_L > \min\{T_U, T_{L+}\}$, the optimal solutions are same as Theorem 2(a); when $c_L \le \min\{T_U, T_{L+}\}$, no offshoring occurs.*
(2b) *If $t_L < t_F$ and $c_L > c_F$, the optimal solutions are same as Theorem 2(b);*

When we compare the results in Theorem 6 with those in Theorem 5, the conditions leading to optimal solutions in different segments are very similar due to the effect of offshoring decentralization. Besides, the retail price decentralization affects the transfer price and retail price, which makes the global supply chain performance even worse when both the cost advantage and tax advantage exist.

5 Global supply chain integration

As we mentioned in Sect. 4 about the difference of global supply chain performance between centralization and decentralization, there is an opportunity to consider the global supply chain integration to reach a win-win outcome, or even a triple-win outcome if the local government's tax revenue is taken into account.

Due to the global recession, many developed countries, have the problems of high unemployment rate and government deficit. The manufacturers and researchers are thinking about "Bring manufacturing back home" (Moser 2011) which is termed Reshoring. In this paper, we do not put our focus on reshoring, however, we consider increasing the local government's tax revenue as a side benefit from improving the global supply chain performance. In the following, we will discuss different schemes which might be applied to the global supply chain to improve the supply chain performance when decentralization exists.

Traditional supply chain coordination contracts have been fully discussed for newsvendor problems (Cachon 2003). When demand is price dependent, the coordination becomes more complicated. This paper has proved that only revenue sharing and price discount contracts with special parameters can coordinate the supply chain. But the price discount requires the retailer's commitment on a price before the retailer chooses the order quantity. Hence, we here uniquely discuss the validity of the revenue sharing contract on the global supply chain coordination. Also considering that the price decentralization (see Theorem 4) with pure foreign tax advantage is the most complicated case, we will only summarize our analysis and findings for that case.

Similar to traditional revenue sharing contract for simple newsvendor problem, we denote ξ $(0 \le \xi \le 1)$ as the supply chain profit allocation proportion between the local company and the total chain profit. The payment from the local company to the HD under revenue sharing contract is denoted as C,

$$C = \lambda T y(P) z + (1-\xi) P y(P) \big(z - \Lambda(z)\big)$$

Thus, the local company's profit after tax is as follows.

$$\pi_L = (1-t_L)\big[\xi P y(P)\big(z-\Lambda(z)\big) - \big(\lambda T + (1-\lambda)c_L\big) y(P) z\big]$$

while the global profit is

$$\pi_{total} = (1-t_L)\left[P y(P)\big(z-\Lambda(z)\big) - \left(\lambda T + (1-\lambda)c_L - \frac{1-t_F}{1-t_L}\lambda(T-c_F)\right) y(P) z\right]$$

According to the structure of the revenue sharing contract, $\pi_L = \xi \pi_{total}$, i.e.,

$$\lambda T + (1-\lambda)c_L = \xi\left[\lambda T + (1-\lambda)c_L - \frac{1-t_F}{1-t_L}\lambda(T-c_F)\right]$$

$\xi = 1$ with $T = c_F$ is the only solution ensuring the equality of the above equation. Such result is consistent with the optimum when $t_F \ge t_L$ where the decentralization shares the same solution with the centralization, but it is not effective when $t_F < t_L$. Therefore the traditional revenue sharing contract is invalid for the global supply chain case if $t_F < t_L$. Similarly, we can prove that the traditional buyback contract and sales rebate contract do not work for $t_F < t_L$.

In the following, we modify the form of traditional revenue sharing contract for the global supply chain where the transfer price and tax issues exist. Besides the chain profit allocation proportion ξ, we define a parameter φ $(\varphi \ge 0)$ which conveys to the local company both information and benefits of foreign tax and production cost. More importantly, φ is not like ξ with the restriction of lower than 100 %. A higher φ denotes a more profit allocation to the local company when ξ is kept constant. λ^* and T^* denote the optimal solution under centralization.

$$C = \lambda^* T^* y(P) z + \left[(1-\xi) P y(P)\big(z-\Lambda(z)\big) - \varphi \frac{1-t_F}{1-t_L}\lambda^*\big(T^*-c_F\big) y(P) z\right] \tag{7}$$

Table 2 The relationship between φ and ξ in a revenue sharing contract

ξ	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4
φ	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2

$(b=3, c_L=1.2, c_F=1.6, t_F=0.1, t_L=0.4)$

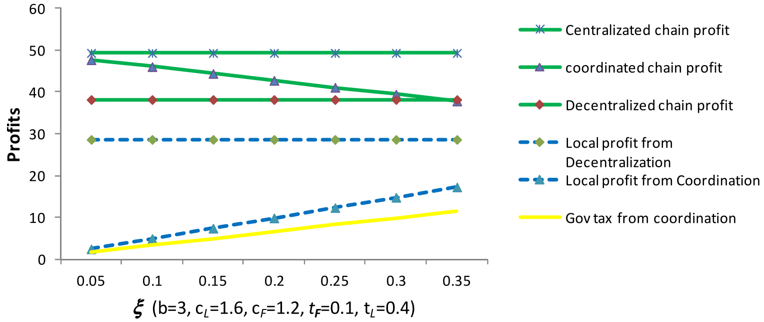

Fig. 6 Performance of revenue sharing contract on global supply chain integration

Let

$$\lambda^* T^* + (1-\lambda^*)c_L - \varphi \frac{1-t_F}{1-t_L}\lambda^*(T^* - c_F) = \xi\left[\lambda^* T^* + (1-\lambda^*)c_L - \frac{1-t_F}{1-t_L}\lambda^*(T^* - c_F)\right]$$

With some algebraic deviation, we have

$$(1-\xi)\big(\lambda^* T^* + (1-\lambda^*)c_L\big) = (\varphi - \xi)\frac{1-t_F}{1-t_L}\lambda^*(T^* - c_F) \tag{8}$$

Given $0 \le \xi \le 1$, we can prove that $\varphi > \xi$ and in most cases $\varphi > 1$. Any pair (ξ, φ) satisfying the equality (Eq. (8)) coordinates the global supply chain. Table 2 illustrates the corresponding value of φ for some given ξ. Using numerical calculation, we find that ξ cannot be extremely large due to the negative effect of φ on the local profit. Therefore, the revenue sharing contract usually cannot arbitrarily allocate profit.

The local government tax revenue increase is illustrated in Fig. 6 where we compare three different cases; centralization, original decentralization and coordinated decentralization. Because the local government shares the pie from global supply chain integration, the revenue sharing contract does not bring a full coordination to the global supply chain, except that ξ is very small which means the local company is given almost zero profit. Recall that the local profit is zero in centralized global supply chain. The findings from the revenue sharing contract are consistent with what we found in previous sections.

6 Concluding remarks

In this paper, we construct a new framework of optimal decision making in global supply chains with price-dependent uncertain demand. The impact of transfer pricing and differential tax rates is addressed in the optimization of global supply chains. This study contributes to the global supply chain management literature by originally formulating a general analytical framework of optimal decision making parallel to the single period newsvendor problem. The double marginalization is also examined in decentralized global supply chains and various contracts are investigated to coordinate the global supply chain.

Our results have the following managerial implications for MNCs and governments. First, MNCs should always offshore if the foreign country has lower relative total production cost. We use relative total production cost to include the effect of other factors including transportation cost and additional administrative costs. Further, we provide MNCs with an opportunity and a threshold to achieve a profitable offshoring when they want to take advantage of the lower foreign tax rates but reluctant to give up the advantage of lower relative local production cost. In addition, a modified coordinating contract are available for MNCs to improve the supply chain performance and smoothly shift income from foreign countries when the local company has stronger power on pricing decision. Finally, we provide strategies to local governments on increasing tax revenue or creating jobs by driving manufacturing back home.

There are a number of ways to extend this research. Our model currently assumes that there is only one demand market—the local market. It is more practical to consider dual markets or multiple markets as we see in the examples of Toyota, Intel, and so on. Offshoring decision will be certainly influenced by the presence of multiple markets. Another possible extension would be to consider the mix supply modes, i.e., the demand could be satisfied from local/foreign production and/or third party sources. The cost charged by the third party source could be higher but providing a prompt replenishment. This issue is very important especially for season products. Tarrifs, transportation costs and other factors can be also incorporated into our framework. Finally, global supply chain coordination needs further investigation by evaluating and creating more effective contracts and schemes.

Appendix

Proof of Theorem 1 Consider the first partial derivatives of $\pi(P, T, z)$ taken with respect to T: $\frac{\partial \pi}{\partial T} = y(P)z(t_L - t_F)$. The function is monotone increasing in T when $t_L > t_F$ and monotone decreasing in T when $t_L < t_F$. Following the sequential procedure in Petruzzi and Dada (1999), we have $T_c^* = T_U$ when $t_L > t_F$, and $T_c^* = c_F$ if $t_L < t_F$. In addition, any feasible transfer price T is optimal when $t_L = t_F$. We have three cases as follows.

Case 1 $t_L > t_F$. Substitute $T_c^* = T_U$ into the profit function, we have,

$$\frac{\partial \pi(T_c^*, P, z)}{\partial P} = \frac{y(P)}{P}\big\{(1 - t_L)\big[(-b + 1)Pz + bzT_U + (b - 1)P\Lambda(z)\big] - (1 - t_F)bz(T_U - c_F)\big\}$$

Let

$$P_c^* = \frac{bz}{(b-1)(z - \Lambda(z))}\frac{(1 - t_L)T_U - (1 - t_F)(T_U - c_F)}{1 - t_L},$$

it is easy to see that $\frac{\partial \pi(T_c^*, P, z)}{\partial P} < 0\ \forall P > P_c^*$ and $\frac{\partial \pi(T_c^*, P, z)}{\partial P} < 0\ \forall P < P_c^*$, thus P_c^* is the unique maximum of $\pi(T_c^*, P, z)$ given z. If we define $M \equiv \frac{(1-t_L)T_U - (1-t_F)(T_U - c_F)}{1-t_L}$, the optimal retail price can be expressed as $P_c^* = \frac{bzM}{(b-1)(z-\Lambda(z))}$.

Following the tax regulation, we should examine if the suggested optimal retail price and transfer price make the local company a non-negative profit. In fact, we have the following the following profit function of the local company via substituting P_c^* and T_c^* into Eq. (1),

$$\pi_L = \frac{y(P)z}{(b-1)(1-t_L)}\left\{T_U\left[(1-t_L)-b(1-t_F)\right]+bc_F(1-t_F)\right\}$$

Therefore, as long as $T_U \leq \frac{bc_F(1-t_F)}{b(1-t_F)-(1-t_L)}$, the non-negativity of local profit can be guaranteed. In the case that the transfer price has a high upper limit, the company should sacrifice partial of the tax benefit and set the ultimate transfer price to be threshold, i.e., $T_c^* = \frac{bc_F(1-t_F)}{b(1-t_F)-(1-t_L)}$. For the ease of future expression, in the notation M, we declare that T_U denotes the true upper limit T_U if the inequality is satisfied or the threshold $\frac{bc_F(1-t_F)}{b(1-t_F)-(1-t_L)}$ otherwise.

Furthermore, the transfer price should not be higher than the retail price, i.e., $T \leq P$. Such inequality leads to $T_c^* \leq \frac{Kc_F(1-t_F)}{K(t_L-t_F)+(1-t_L)}$. Let $T_{\leq P} = \frac{Kc_F(1-t_F)}{K(t_L-t_F)+(1-t_L)}$, we can show that $T_{\leq P} > c_F$.

We give out the optimal z as follows. The optimal profit function is

$$\pi\left(T_c^*, P_c^*, z\right) = (1-t_L)\left[y\left(P_c^*\right)z\left(P_c^*-M\right)-P_c^* y\left(P_c^*\right)\Lambda(z)\right]$$

Except the scale $(1-t_L)$, the structure of $\pi(T_c^*, P_c^*, z)$ is same with that in Theorem 2 of Petruzzi and Dada (1999). Thus, if $b \geq 2$ and $r(z) = \frac{\phi(z)}{1-\Phi(z)}$ is increasing for $A \leq z \leq B$, which implies $2r(z)^2 + dr(z)/dz > 0$, there is a unique optimal value z_c^* which satisfies $\Phi(z_c^*) = \frac{z_c^*+(b-1)\Lambda(z_c^*)}{bz_c^*}$.

Case 2 $t_L < t_F$. $T_c^* = c_F$, $\frac{\partial\pi(T_c^*,P,z)}{\partial P} = (1-t_L)\frac{y(P)}{P}[-(b-1)P(z-\Lambda(z))+bzc_F]$. Let $P_c^* = \frac{bzc_F}{(b-1)(z-\Lambda(z))}$, which is the unique maximizer of $\pi(T_c^*, P, z)$ given z. In addition, according to Proposition 2 later, P_c^* is a qualified retail price which makes the local company owns a positive profit.

Now, we substitute P_c^* into $\pi(T_c^*, P, z)$ and optimize over z. $\pi(T_c^*, P_c^*, z) = (1-t_L)[y(P_c^*)z(P_c^*-c_F) - P_c^* y(P_c^*)\Lambda(z)]$. We have the same optimal conditions and same optimal solution z_c^* as that in case 1. □

Proof of Proposition 1 Simply follow the Theorem 2 of Petruzzi and Dada (1999). □

Proof of Theorem 2 Based on Proposition 2, we substitute $P_d^*(z, T)$ and z_d^* into $\pi(T)$, and take the first order condition with respect to T, then we have

$$\frac{\partial\pi(T)}{\partial T} = \left\{\left[t_L - t_F - b(1-t_F)\right]T + bc_F(1-t_F)\right\}\cdot azK(KT)^{-(b+1)}$$

where $K = \frac{bz}{(b-1)[z-\Lambda(z)]} > 0$, thus $azK(KT)^{-(b+1)} > 0$ for all feasible values, therefore π is unimodal in T. Considering the transfer price should meet the condition $c_F \leq T \leq P$, we have $T_d^* = \frac{bc_F(1-t_F)}{b(1-t_F)-(t_L-t_F)}$ if $t_L > t_F$. Note that $\frac{bc_F(1-t_F)}{b(1-t_F)-(t_L-t_F)} \leq c_F$ if $t_L \leq t_F$, but we need the transfer price not less than the foreign manufacturing cost, thus $T_d^* = c_F$ if $t_L \leq t_F$. □

Proof of Theorem 3 Only the proof of (1b) is shown here. According to the proof of Theorem 1, given λ and T, the optimal retail price is in the form of

$$P(\lambda, T) = K\left[\lambda T + (1-\lambda)c_L - \frac{1-t_F}{1-t_L}\lambda(T-c_F)\right]$$

Then taking the first order condition with respect to T and λ, respectively

$$\frac{\partial\pi(T,\lambda)}{\partial T} = (b-1)y(P)\lambda(t_F - t_L)\big[-(K-1)\big(z-\Lambda(z)\big) + \Lambda(z)\big] > 0,$$

$$\begin{aligned}\frac{\partial\pi(T,\lambda)}{\partial \lambda} &= (b-1)y(P)\big[(1-t_L)(T-c_L) - (1-t_F)(T-c_F)\big] \\ &\quad \times \big[-(K-1)\big(z-\Lambda(z)\big) + \Lambda(z)\big]\end{aligned}$$

Let $Q = \frac{c_F(1-t_F)-(1-t_L)c_L}{t_L-t_F}$. When $t_L > t_F$ and $c_L < c_F$, $Q > c_F$. If $T_U \le Q$, $\frac{\partial\pi(\lambda)}{\partial\lambda} < 0$ for any $\lambda \ge 0$. We conclude that no offshoring exists when $T_U \le Q$.

On the other side, if $T_U > Q$, we have $\frac{\partial\pi(\lambda)}{\partial\lambda}|_{\lambda=0,T>Q} > 0$ which assures that given any $T > Q$, $\pi(\Delta\lambda) > \pi(\lambda = 0)$, i.e, a profit jump at $\lambda = 0$, where $\Delta\lambda$ refers to a small value. Note that $\pi(\lambda = 0)$ denotes the profit from no offshoring.

But the transfer price T can't be an arbitrary value; It should satisfy another two conditions besides $T > Q$: (I) $\pi_L(T) \ge 0$ and (II) $T \le P$. Recall that the retail price is in the form $P(\lambda, T) = K(\lambda T + (1-\lambda)c_L)$. Given any $T > Q$, $\lim_{\lambda\to 0} P(\lambda, T) = Kc_L$. Therefore, if $Kc_L > Q$, there exists $\lambda > 0$ and $P(\lambda, T) \ge T$ is satisfied.

The criterion $\pi_L(T) \ge 0$ requests $T \le \frac{(1-\lambda)(1-t_L)c_L+\lambda bc_F(1-t_F)}{\lambda[b(1-t_F)-(t_L-t_F)]}$. Taking into account the total profit increases as T increases, the form of the optimal transfer price must be like

$$T(\lambda) = \frac{(1-\lambda)(1-t_L)c_L + \lambda bc_F(1-t_F)}{\lambda[b(1-t_F)-(t_L-t_F)]}$$

Along with the criterion $T(\lambda) \le P$, i.e.,

$$T(\lambda) \le K\frac{(1-\lambda)(1-t_L)c_L + \lambda(1-t_F)c_F}{(1-t_L)+K\lambda(t_L-t_F)},$$

we can deduct the optimal λ^* if it exists. To be specific,

$$\bar{a}\lambda^2 + \bar{b}\lambda + \bar{c} \ge 0 \tag{9}$$

where

$$\begin{aligned}\bar{a} &= K(b-1)(1-t_F)(1-t_L)(c_F-c_L) \\ \bar{b} &= -K(1-t_F)(1-t_L)c_L + (1-t_L)^2c_L + (Kc_L-c_F)b(1-t_L)(1-t_F) \\ \bar{c} &= -c_L(1-t_L)^2\end{aligned}$$

If $c_L < c_F$ and $t_L > t_F$, we have $\bar{a} > 0$ and $\bar{c} < 0$, thus the shape of the quadratic curve (Eq. (9)) is upward, so if $\frac{-\bar{b}+\sqrt{\bar{b}^2-4\bar{a}\bar{c}}}{2\bar{a}} \le 1$, i.e., $Kb-(K+b) \ge 0$, the optimal solution is $\lambda^* = \frac{-\bar{b}+\sqrt{\bar{b}^2-4\bar{a}\bar{c}}}{2\bar{a}}$. □

Proof of Theorem 4 Similar to the proof of Theorem 3 except that the Proposition 3 has to be considered. □

Proof of Discussion 1 Due to the constraint $T \le P$, we have to explore the optimal solution from two different conditions, i.e., Path A: looking for a best T with an endogenous optimal $\lambda(T)$, and Path B: looking for a best λ with an endogenous optimal $T(\lambda)$.

Path A: Based on Proposition 3, substituting $P^*_{cd}(z^*_{cd})$ and z^*_{cd} into $\pi(T, \lambda)$, and taking the first order condition with respect to T, we can prove that π is unimodal in T, and

$$T^*(\lambda) = \frac{\lambda b c_F(1-t_F) - (1-\lambda)c_L(t_F - t_L)}{\lambda[b(1-t_F) - (t_L - t_F)]} \tag{10}$$

When $t_L > t_F$ and $c_L < c_F$, $\pi(T^*(\lambda), \lambda)$ is decreasing in λ from the evidence

$$\begin{aligned} &\frac{\partial \pi(T^*_{cd}(\lambda), \lambda)}{\partial \lambda} \\ &\quad = a(1-t_F)(c_L - c_F)z^*_{cd}\left\{b\frac{bz^*_{cd}}{(b-1)(z^*_{cd} - \Lambda(z^*_{cd}))}(1-t_F)\frac{\lambda(c_L - c_F) - c_L}{bt_F - t_F - b + t_L}\right\}^{-b} \end{aligned}$$

Note that the constraint $Q \le T \le P$ should be taken into account before constructing the optimal solutions. $T \le P$ is equivalent to the following inequality by simple algebraic derivation:

$$\tilde{a}\lambda^2 + \tilde{b}\lambda + \tilde{c} \ge 0 \tag{11}$$

where

$$\begin{aligned} \tilde{a} &= Kb(1-t_F)(c_F - c_L) \\ \tilde{b} &= c_L(t_L - t_F) + b(1-t_F)(Kc_L - c_F) \\ \tilde{c} &= c_L(t_F - t_L) \end{aligned}$$

If $c_L < c_F$ and $t_L > t_F$, we have $\tilde{a} > 0$ and $\tilde{c} < 0$, thus the shape of the quadratic curve (Eq. (11)) is upward, so the minimal feasible value of λ is optimal, i.e., $\lambda^* = \frac{-\tilde{b}+\sqrt{\tilde{b}^2 - 4\tilde{a}\tilde{c}}}{2\tilde{a}}$. If $T^*(\lambda^*) < Q$, there is no optimum (due to $\frac{\partial T^*(\lambda)}{\partial \lambda} < 0$) from the path A, noticing that

$$T^*(\lambda) = \frac{\lambda b c_F(1-t_F) - (1-\lambda)c_L(t_F - t_L)}{\lambda[b(1-t_F) - (t_L - t_F)]}$$

increases as λ decreases.

Path B: Similarly, given T, we can easily find the optimal offshoring proportion λ

$$\lambda^*(T) = \frac{c_L[(1-t_F)(T-c_F) - (1-t_L)(T-c_L)]}{(T-c_L)[(b-1)(1-t_F)(T-c_F) + (1-t_L)(T-c_L)]}$$

Again, the optimal solution must meet $T \le P$, which is equivalent to the following inequality by simple algebraic derivation:

$$\hat{a}T^2 + \hat{b}T + \hat{c} \le 0 \tag{12}$$

where

$$\begin{aligned} \hat{a} &= b(1-t_F) - (t_L - t_F) \\ \hat{b} &= -b(1-t_F)c_F - b(1-t_F)Kc_L - \big(c_L(1-t_L) - (1-t_F)c_F\big) \\ \hat{c} &= bKc_L(1-t_F)c_F \end{aligned}$$

Under the situation $c_L < c_F$ and $t_L > t_F$, we have $\hat{a} > 0$, $\hat{b} < 0$ and $\hat{c} < 0$, so there is a feasible range for T. More important, Q makes equality. When $Kc_L > Q$, the optimal transfer price is in the form

$$T^* = \frac{-\hat{b} + \sqrt{\hat{b}^2 - 4\hat{a}\hat{c}}}{2\hat{a}}$$

We refer π_A and π_B to the total profits derived from Path A and B, respectively. Hence,

$$\pi_A = \pi\left(\lambda_A^*, T_A^*(\lambda_A^*) = \frac{\lambda_A^* b c_F(1-t_F) - (1-\lambda_A^*)c_L(t_F - t_L)}{\lambda_A^*[b(1-t_F) - (t_L - t_F)]}\Big|\lambda_A^* = \frac{-\tilde{b} + \sqrt{\tilde{b}^2 - 4\tilde{a}\tilde{c}}}{2\tilde{a}}\right)$$

while

$$\pi_B = \pi\left(\lambda_B^*(T_B^*) = \frac{c_L[(1-t_F)(T_B^* - c_F) - (1-t_L)(T_B^* - c_L)]}{(T - c_L)[(b-1)(1-t_F)(T_B^* - c_F) + (1-t_L)(T_B^* - c_L)]}, T_B^*\Big|T_B^* \right.$$
$$\left. = \frac{-\hat{b} + \sqrt{\hat{b}^2 - 4\hat{a}\hat{c}}}{2\hat{a}}\right)$$

In fact, we can prove $\lambda_B^*(T_A^*(\lambda_A^*)) < \lambda_A^*$, but the solution $(\lambda_B^*(T_A^*(\lambda_A^*)), T_A^*(\lambda_A^*))$ is not feasible due to an invalid $P < T$, though bringing a higher profit. Therefore, the comparison π_A and π_B simply makes decision on the optimal solution for the headquarters. □

Proof of Theorem 5 Given fixed P, z, and T, consider the first partial derivatives of π_L taken with respect to λ:

$$\frac{\partial \pi_L}{\partial \lambda} = y(P)z(c_L - T)$$

(1) If $c_L < c_F$, it is easy to see $c_L - T < c_F - T \leq 0$, thus $\frac{\partial \pi_L}{\partial \lambda} < 0$. The optimal λ_{dc}^* for the retailer is $\lambda_{dc}^* = 0$, i.e., no offshoring.

(2) If $c_L > c_F$, then $\lambda_{dc}^* = 0$ given $T > c_L$, $\lambda_{dc}^* = 1$ given $c_F \leq T < c_L$, and $\forall \lambda \in [0, 1]$ is optimal given $T = c_L$. Note that the retailer and headquarters play a Stackelberg game, where the headquarters act as the leader. Given the retailer's response function, we analysis the decision of the headquarters.

Consider the first partial derivatives of π taken with respect to T:

$$\frac{\partial \pi(P, T, z, \lambda(P, T, z))}{\partial T} = y(P)z\lambda(t_L - t_F)$$

It is easy to find that if $t_L < t_F$, then $T_{dc}^* = c_F$, and $\lambda_{dc}^* = 1$;

(2a) if $t_L > t_F$, we discover that the local company makes decision on λ depending on the difference between c_L and the transfer price to be set by the headquarters. Therefore, when $c_L > \min\{T_U, T_{L+}\}$, $\lambda_{dc}^* = 1$, and all other optimal solutions are same as Theorem 1(a). Otherwise, offshoring occurs.

(2b) if $t_L < t_F$, the optimal solutions are same as in Theorem 1(b).

□

Proof of Theorem 6 Proof is similar to Theorem 5 except that Proposition 1 should be considered here. □

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