Manufacturing & Service Operations Management

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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MANUFACTURING & SERVICE OPERATIONS MANAGEMENT
Vol. 17, No. 3, Summer 2015, pp. 384–398
ISSN 1523-4614 (print) | ISSN 1526-5498 (online)

http://dx.doi.org/10.1287/msom.2015.0526

Manufacturing Capacity Decisions with Demand Uncertainty and Tax Cross-Crediting

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The U.S. tax law taxes the global income of multinational firms (MNFs) at their home country tax rate. To avoid double taxation, it permits *tax cross-crediting*. Through this strategy, global firms can use excess foreign tax credits (FTCs), the portion of foreign tax payments that exceed their home country tax liabilities, generated from a subsidiary located in a high-tax country to offset the tax liabilities of their low-tax divisions. This paper studies manufacturing capacity decisions in the subsidiary of an MNF with tax cross-crediting. Casting the problem on a newsvendor model, and assuming the objective of maximizing the global firm's worldwide after-tax profits, we show that the optimal capacity decision under the effects of tax cross-crediting can behave very differently from that of the traditional newsvendor model. In particular, we show that an improvement in the firm's after-tax profitability (through tax cross-crediting, an increased profit margin, or a reduced tax rate) might reduce the optimal capacity and that the optimal capacity decision under certain circumstances can be made without the knowledge of the demand distribution. We also discuss the issue of motivating the division manager to use an after-tax performance measure with a managerial tax rate.

Keywords: global supply chain management; international tax planning; foreign tax credit; tax cross-crediting
History: Received: November 18, 2013; accepted: January 21, 2015. Published online in *Articles in Advance* April 17, 2015.

1. Introduction

The globalization of the world's economy allows multinational firms (MNFs) to expand their global businesses rapidly beyond their home countries. Many of these companies increasingly recognize the strategic value of aligning international tax planning with their global supply chain decisions (Murphy and Goodman 1998). One of the major challenges for an MNF in developing such a so-called *tax-aligned* or *tax-effective* global supply chain strategy is to effectively motivate and coordinate the supply chain decisions at its subsidiaries to achieve the global company's overall operational and financial objectives.

Wilson (1993) conducted a study of nine U.S. MNFs to determine how they integrate tax planning with supply chain decisions, such as capacity expansion and product production. Most of the firms surveyed used pretax measures to evaluate their division managers' performances. However, some firms recognized that pretax measures can create potential conflicts between a global firm's goal of maximizing its worldwide after-tax profits and its local operations decisions that are based on pretax performance. They therefore made various informal and formal adjustments to managerial books to mitigate the potential frictions. Two firms in the study used certain forms of after-tax performance measures. However, these after-tax measures "did not provide individual managers with a direct incentive to coordinate activities such as souring" (Wilson 1993, p. 228). Informal communication of tax planning was also deployed to make further adjustments. The Wilson (1993) study demonstrates the complexity of designing and implementing decentralized performance measures in an MNF to "ensure the correct distribution of (production) quantities to maximize after-tax worldwide income" (p. 219). Further, it suggests that many MNFs used pretax performance measures simply because "determining the correct tax rate for these after-tax performance measures is a complex, if not impossible, problem that requires considerable coordination between corporate and foreign tax planners" (p. 220).

Ample empirical evidence suggests that MNFs with greater tax planning opportunities tend to use after-tax performance measures as incentives for their managers to explicitly consider the effects of taxes on their operations decisions. Specifically, large companies with a greater number of operating divisions and a higher level of multinational operations are found to be more likely to select after-tax rather than pretax measures (see, e.g., Newman 1989, Atwood et al. 1998, Carnes and Guffey 2000, Phillips 2003). However, most analytical models in the operations management literature that characterize operations decisions use pretax financial objectives (typically cost minimization or pretax profit maximization). Recently, Huh and Park (2013) and Shunko et al. (2014) have considered the after-tax objective and examined the MNF's transfer pricing decision in light of both operations and tax incentives.

In this paper, we examine the effect of international taxation on the optimal manufacturing capacity decision at a U.S. MNF's overseas subsidiary. U.S.-based MNFs must pay taxes for their worldwide income at the U.S. (home country) tax rate. To avoid double taxation, Section 901 of the Internal Revenue Code permits foreign tax credits (FTCs) for the taxes an MNF has paid to foreign countries. Thus, a subsidiary located in a *high-tax* country (with a tax rate higher than that of its home country) already will have paid more taxes overseas when its income is repatriated to its parent company and thus generates excess FTCs, or *excess credits* (ECs). These ECs can be used to offset the tax obligations for the income remitted from the global firm's subsidiaries located in low-tax countries. This practice is referred to as *tax cross-crediting* (Scholes et al. 2009). A global firm is said to be in an excess credit position (or to have binding foreign tax credits) if its total foreign tax credits are more than enough to offset its total foreign tax liabilities.

Because both the tax rates and the amount of excess credits that a global firm possesses determine the effective tax rate of the low-tax division, the tax rates and the firm's excess credit position naturally are expected to influence its manufacturing capacity decisions. Our theoretical study of the effect of international taxation on manufacturing capacity decisions is motivated by several related empirical findings. In particular, Grubert and Mutti (1991, 2000) and Hines and Rice (1994) use data on property, plant, and equipment (PPE), which is closely related to real investment, and report a significantly strong relationship between the foreign country tax rate and the MNFs' PPE capacity decisions for their foreign subsidiaries. Hines (1996) provides empirical evidence that the effects of tax rates on an MNF's PPE capacity decisions depend on the availability of foreign tax credits for the MNF. Interestingly, Swenson (1994) provides evidence confirming the hypothesis (Scholes and Wolfson 1990) that a higher foreign tax rate might raise the MNF's investment in its foreign subsidiary when the MNF's home country permits foreign tax credits.

We study the capacity decision problem by expanding the traditional newsvendor model to include the after-tax profit maximization performance measure and the tax cross-crediting consideration. Specifically, we examine the optimal capacity decision at an MNF's subsidiary located in a low-tax country. Our study indicates that when facing tax cross-crediting opportunities, the capacity decision at the low-tax division can exhibit characteristics that are surprisingly different from that of the traditional inventory models. For example, conventional wisdom suggests that a division manager's decision should be more aggressive (e.g., to build more capacity) as his or her product becomes more profitable. This intuition no longer holds when the division manager is given the incentive to cross-credit a certain amount of ECs. We show that as the ECs increase, which raises the division's after-tax profits, the division's optimal capacity does not necessarily rise as well. Instead, as the ECs increase from zero to a sufficiently high level, the optimal capacity first decreases, then increases, and finally stays flat. We also show that as the product's profit margin increases, the optimal capacity does not necessarily increase. Instead, as the profit margin increases from zero to a sufficiently high level, the optimal capacity first increases, then decreases, and finally increases.

Another surprising effect of tax cross-crediting on the manufacturing capacity decision is that within a modest range of ECs, the corresponding optimal capacity decision can be determined simply by matching the maximum tax liabilities with the existing ECs. In other words, the concern of tax planning mutes the concern of matching supply with uncertain demand and becomes the sole determinant for the optimal capacity decision. Further, this modest range of ECs widens when the difference between the subsidiary's local tax rate and the home country tax rate becomes larger.

Our characterization of the optimal capacity has implications for how MNFs should use an internal managerial tax rate to induce their subsidiaries to make their capacity investment decision to maximize the company's worldwide after-tax expected profits. We show that parent companies can use an optimal managerial tax rate in an after-tax performance measure to incentivize division managers to make a globally optimal capacity decision, and that such an optimal managerial tax rate can be even larger than the home country tax rate (which is already higher than the local tax rate). We also compare three easily implementable and intuitive performance measures: namely, measures based on pretax, after-local-tax, and after-home–country-tax incomes. See Phillips (2003) for a survey of the pretax and after-tax performance measures used by 206 U.S.-based MNFs. We show that if the existing ECs are low (high), then the MNF's best choice among the three performance measures is the after-home-country-(local) tax measure.

To sharpen our study's insights on the effects of tax planning on the MNF's manufacturing capacity investment decisions, our analysis initially focuses on a newsvendor-style model, with the objective of maximizing the expected after-tax profits within a planning year. The requirement that the capacity investment decision must be made before the realization of uncertain demand reflects an important feature of products with a short selling season (or life cycle) and/or a relatively long lead time in capacity installation. We then discuss the robustness of our results by extending the base model to a number of more general settings, including general profit functions, carryback and carryforward of losses and ECs in a multiperiod setting, endogenous repatriation decisions, and endogenously generated ECs.

The remainder of this paper is organized as follows: Section 2 discusses the related literature. Section 3 describes the model. Section 4 characterizes the optimal capacity decision in a benchmark case with the objective of after-tax profit maximization, but without tax cross-crediting. Section 5 characterizes the optimal capacity decision with tax cross-crediting and offers some insights into the effects of excess credits, profit margin, and tax rates on the optimal capacity decision. Section 6 addresses the issue of how the global firm can use internal managerial tax rates to effectively motivate division managers to make desirable capacity decisions. Section 7 discusses extensions of the newsvendor model to a number of more general settings. Section 8 concludes the paper.

2. Literature

Our work falls into the area of research that integrates international tax planning with global operational decisions. Many of the papers in this area focus on income shifting, a strategy used by MNFs to shift their incomes from high-tax divisions to subsidiaries in low-tax jurisdictions through transfer pricing (Scholes et al. 2009). Some of these papers consider the integration of transfer pricing and operations decisions to improve the performance of an MNF's global supply chain operations (Cohen et al. 1989, Kouvelis and Gutierrez 1997, Vidal and Goetschalckx 2001, Goetschalckx et al. 2002, Miller and de Matta 2008). The interactions of transfer pricing and production/distribution decisions are typically formulated as nonlinear mathematical models, which are then often solved by heuristics.

Huh and Park (2013) use the newsvendor framework to compare the supply chain performance under two commonly used transfer pricing methods for tax purposes. Shunko et al. (2014) study a global firm that sells a product in its domestic market but produces the product either at a subsidiary or an external manufacturer located in a foreign country. They investigate various centralized and decentralized production and pricing (including transfer pricing) strategies that balance the trade-offs between tax costs and production costs.

We do not address the issue of income shifting. We assume that the low-tax subsidiary invests in its manufacturing capacity decision to satisfy local demand and that no intercompany (or cross-division) transactions between the global firm's divisions influence those decisions. Thus, our paper has a distinct focus on the effects of tax cross-crediting on the optimal capacity decision.

Some papers in the research area of tax and operations interface, including Munson and Rosenblatt (1997), Wilhelm et al. (2005), Li et al. (2007), and Hsu and Zhu (2011), study the effects of indirect taxes, such as tariff and value-added taxes, on operational decisions. These papers do not consider the interaction of incomes from high-tax and low-tax divisions of an MNF.

More generally, our paper is also related to studies in the global supply chain literature that include after-tax profit maximization as their objectives (for a comprehensive review, see Meixell and Gargeya 2005). Most of these papers consider deterministic profits, and the optimal decisions, therefore, often guarantee positive profitability. In these cases, the effects of taxes can often be simply treated as part of the variable costs of the products. For example, they would add a percentage of a tariff to the cost of a product imported into a country or subtract a percentage of the corporate taxes from the product made in a country. Furthermore, these papers do not consider tax cross-crediting.

3. The Models

Suppose that an MNF with home country tax rate $\tau_h > 0$ has a wholly-owned subsidiary incorporated in a low-tax foreign country with tax rate $\tau_l < \tau_h$. We assume that the subsidiary sells a single product to its uncertain local market in a single selling season at a per-unit selling price (or retail price) p. Because of the long lead time for capacity installation, the capacity q has to be decided in advance of the selling season, at a per unit installation cost c, where $p > c$. The market demand, denoted by D, is a random variable with probability density function $g(\cdot)$ and distribution function $G(\cdot)$ with the support $[0, +\infty)$. After the random demand D is realized, the subsidiary collects pretax profits $R(q, D)$, where $R(q, D) = p\min(q, D) - cq$.

Without considering tax issues, the traditional operations literature chooses a capacity $q^o(0)$ that maximizes the expected pretax profits (with a tax rate of zero), i.e., $q^o(0) = \arg\max_q \{E_D[R(q, D)]\}$. However, when tax is considered, $q^o(0)$ might not coincide with the quantity that maximizes the firm's expected after-tax profits. Suppose that tax rate $\tau \geq 0$ applies to the firm's pretax profits $R(q, D)$, whether they are positive or negative; that is, the firm is levied at the tax rate τ when it is profitable, and it receives a subsidy at the same rate τ for its losses. Then, the quantity $q^o(0)$, which is optimal for the traditional model, also maximizes the expected after-tax profits because taxation only scales the profits (positive or negative) by $(1 - \tau)$ and thus does not affect the optimal quantity. In practice, however, the tax rate for such a firm is τ when it is profitable, but it becomes zero when the firm incurs losses. With this phenomenon of *tax asymmetry* (Eldor and Zilcha 2002), the quantity that maximizes the expected after-tax profits is

$$q^o(\tau) = \arg\max_q E_D[R(q, D) - \tau R^+(q, D)], \tag{1}$$

where $R^+(q, D) = \max\{0, R(q, D)\}$.

Note that when considering the tax asymmetry based on local taxes, the low-tax subsidiary should produce the quantity $q^o(\tau_l)$ that maximizes the subsidiary's expected after-local-tax profits. However, because $q^o(\tau_l)$ disregards the global firm's worldwide FTC planning opportunities, the quantity might still be suboptimal for the MNF. Suppose that as a result of its international tax planning, the MNF has decided to remit to the home country a certain amount of deferred repatriation income from its high-tax subsidiaries. Such a repatriation plan generates a certain amount of ECs, denoted by C, in the planning year. Meanwhile, for any given quantity q and realized market demand D, the low-tax division's pretax profits are $R(q, D)$, which lead to local taxes of $\tau_l R^+(q, D)$ and tax liabilities of $(\tau_h - \tau_l)R^+(q, D)$. As a result of tax cross-crediting, the global firm can offset part (or all) of the tax liabilities up to the available ECs, C. Consequently, the global firm's net repatriation taxes owed to its home country are $(\tau_h - \tau_l)R^+(q, D) - \min(C, (\tau_h - \tau_l)R^+(q, D))$. The global firm's expected worldwide after-tax profits, denoted by $\Pi(q, C)$, can be written as

$$\Pi(q, C) = E_D\big[R(q, D) - \tau_h R^+(q, D) + \min(C, (\tau_h - \tau_l)R^+(q, D))\big]. \tag{2}$$

Let $q^*(C) = \arg\max_q \Pi(q, C)$ be the global firm's optimal capacity decision under both tax asymmetry and tax cross-crediting.

4. Optimal Capacity Decision Without Tax Cross-Crediting

As a benchmark for later discussions, we examine the effect of tax asymmetry on the optimal capacity decision $q^o(\tau)$ defined by (1), assuming the objective of maximizing the expected after-tax profits. For fixed D, it is verifiable that $R(q, D) - \tau R^+(q, D)$ is concave in q. Thus, the objective function of problem (1) is also concave in q. The concavity property implies that the optimal solution $q^o(\tau)$ can be obtained through the first-order condition, which we derive next using a marginal cost analysis.

Given any capacity q, if the realized demand exceeds the supply (i.e., $D > q$), the excess demand is lost, and the firm loses the opportunity to earn additional profits because of insufficient supply. Thus, the marginal underage cost (i.e., the gain in the after-tax profits by satisfying a unit of lost demand) is equal to $(1 - \tau)(p - c)$ ($p > c$ to ensure profitability). Because underage occurs when demand exceeds supply, the expected marginal underage cost is $(1 - G(q))(1 - \tau)(p - c)$.

When demand is lower than supply (i.e., $D < q$), the leftover inventory has zero value, and the firm incurs overstock costs. However, in contrast to the result for the marginal understock cost, which is a constant and does not depend on how much excess demand is lost, the marginal overage cost depends on the demand realization and on whether the division is profitable. Specifically, two distinct cases arise. On the one hand, if $D < cq/p$, the firm's sales revenue pD is not even enough to recoup the capacity cost cq, resulting in net losses and thus zero tax payment. The marginal overstock cost is simply the unit capacity cost c. On the other hand, if $D \in [cq/p, q)$, the firm makes profits and pays taxes at rate τ. The firm's marginal overstock cost in this case is $(1 - \tau)c$ because it receives a tax deduction τc from the unit capacity installation cost c. Because these two cases occur with probability $G(cq/p)$ and $G(q) - G(cq/p)$, respectively, the expected marginal overstock cost is $G(cq/p)c + (G(q) - G(cq/p))(1 - \tau)c$.

Note that as q increases from zero to positive infinity, the expected marginal understock cost decreases from $(1 - \tau)(p - c)$ to zero, and the expected marginal overstock cost increases from zero to c. From the marginal cost analysis we can see that the firm's optimal capacity $q^o(\tau)$ is the unique solution to the equation

$$G(cq/p)c\frac{\tau}{1 - \tau} + G(q)c = (1 - G(q))(p - c), \tag{3}$$

where the first term captures the effect of the tax asymmetry, whereas the second and third terms are the typical newsvendor marginal costs.

Proposition 1. *The optimal capacity without tax cross-crediting $q^o(\tau)$ increases as τ decreases, or c decreases, or p increases.*

All the proofs can be found in the online appendix (available as supplemental material at http://dx.doi.org/10.1287/msom.2015.0526). The first part of Proposition 1 indicates that the optimal capacity decision $q^o(\tau)$, with tax consideration, is smaller than $q^o(0)$, which is the optimal newsvendor quantity without considering tax, and that the difference becomes more significant as the tax rate τ increases. This distinctive result is caused by the interplay between demand uncertainty and a salient feature of the tax system whereby taxes are charged only when the firm registers nonnegative profits. Specifically, because of demand uncertainty, perfectly matching supply with demand is impossible, resulting in two types of costs for supply/demand mismatch: overstock cost and understock cost. If the tax simply scales down both types of costs by a constant factor, then the optimal capacity would not change. However, when understock occurs, the firm always makes profits, and thus the understock cost is scaled down by the tax rate τ; in contrast, when overstock occurs, the possibility arises that the firm incurs losses, in which case the scale-down of the overstock cost does not occur. In other words, the tax asymmetry effect mitigates the concern of understocking more than it does the concern of overstocking, thus resulting in more conservative capacity decisions than would otherwise occur in the traditional newsvendor model.

The results in Proposition 1 also support the intuition, which holds for the traditional newsvendor model, that a division manager's decision tends to become more aggressive in response to a change in business conditions that make his or her product more profitable when the unit capacity cost decreases, or the unit selling price increases, or the tax rate decreases. We show in the next section that this intuition no longer holds for the firm's optimal capacity decision in the case of tax cross-crediting.

5. Optimal Capacity Decision With Tax Cross-Crediting

This section examines the MNF's optimal capacity decision with the consideration of tax cross-crediting. Based on Theorem 5.5 in Rockafellar (1970, p. 35), which says that the pointwise infimum of an arbitrary collection of concave functions is also concave, the MNF's objective function defined in Equation (2) is concave in q; therefore, its optimum $q^*(C)$ can be determined by the first-order condition.

However, characterizing the optimal capacity decision $q^*(C)$ is no longer as straightforward as in the benchmark discussed in the previous section. With the addition of the home country tax rate τ_h and the interplay of tax asymmetry and tax cross-crediting, some of the insights from the marginal cost analysis for the benchmark are no longer applicable. To illustrate, suppose that the division makes a capacity decision q and that the realized demand exceeds the capacity (i.e., $D > q$). The division's pretax profits are $(p-c)q$, which incur $(\tau_h - \tau_l)(p-c)q$ tax liabilities. In contrast to the benchmark model, in which a single tax rate applies to any marginal profit, now the tax rate applied to the marginal profit depends on whether the available ECs can be fully used to offset the tax liabilities. In particular, if the ECs are in shortage (i.e., if $C < (\tau_h - \tau_l)(p-c)q$), the marginal profit is taxed at the home country tax rate τ_h. However, if the ECs are sufficient to offset the tax liabilities (i.e., if $C > (\tau_h - \tau_l)(p-c)q$), then the tax rate applied to the marginal profit becomes the local tax rate τ_l.

Let $q_1(C) = C/[(\tau_h - \tau_l)(p-c)]$. Three regions of capacity q emerge from the observations just made above: $q < q_1(C)$, $q > q_1(C)$, and $q = q_1(C)$. These regions are labeled as Regions H, L, and M, respectively. In the following subsections, we derive the necessary and sufficient conditions under which the optimal capacity decision falls in each of the three regions. In each case, we characterize the optimal capacity decision. Then we discuss the effects of a few key business factors, such as the ECs, the retail price, and the tax rates, on the optimal capacity decision.

5.1. Characterization of Optimal Capacity Decision

5.1.1. Region H: $q < q_1(C)$. Suppose that the optimal capacity $q^*(C)$ satisfies $q^*(C) < q_1(C)$, which implies that the available ECs are sufficiently large that they will always exceed the tax liabilities generated by the division, even if the entire capacity $q^*(C)$ is used up. Thus, the repatriation tax $\tau_h - \tau_l$ generated by one dollar of local profit can be fully offset by the ECs so that the local country tax rate τ_l is applied to every dollar of profits generated by the division. As a result, $\Pi(q, C)$ can be rewritten as

$$\Pi(q, C) = E_D[R(q, D) - \tau_l R^+(q, D)].$$

We can, therefore, intuitively expect the global firm to choose $q^*(C) = q^o(\tau_l)$, the capacity that maximizes the expected after-local-tax profits. Under what conditions does $q^o(\tau_l)$ fall into Region H (i.e., $q^o(\tau_l) < q_1(C)$)? The answer follows directly from the definition of $q_1(C)$: $q^o(\tau_l) < q_1(C)$ if and only if $C > \bar{C}$, where

$$\bar{C} = (\tau_h - \tau_l)(p-c)q^o(\tau_l). \tag{4}$$

The previous discussion leads to the following proposition.

Proposition 2. *The firm's optimal capacity $q^*(C)$ lies in Region H if and only if $C > \bar{C}$. When it does, $q^*(C) = q^o(\tau_l)$.*

The necessary and sufficient condition in Proposition 2 further suggests that when C is no larger than $\bar{C}$ (i.e., $C \le \bar{C}$), any quantity in Region H (i.e., $q < q_1(C)$), cannot be optimal. The rationale for this claim can be explained as follows. At any quantity $q < q_1(C)$, the firm will never be able to fully use the ECs (C) and thus always enjoys the lower tax rate τ_l, in which case the critical quantity that balances the two types of supply/demand mismatch cost is $q^o(\tau_l)$. By the definition of $\bar{C}$ in (4), the condition $C \le \bar{C}$ can also be expressed as $q_1(C) < q^o(\tau_l)$, implying that producing $q_1(C)$ is already too conservative with respect to the critical quantity $q^o(\tau_l)$. Producing any quantity $q < q_1(C)$ is even more conservative and therefore suboptimal.

5.1.2. Region L: $q > q_1(C)$. For any given capacity $q > q_1(C)$, if the realized demand exceeds the capacity ($D > q$), the tax liabilities $(\tau_h - \tau_l)(p-c)q$ generated by the division are more than enough to redeem the entire ECs (C). Thus, the marginal gain in pretax profits from selling an additional unit of the product is subject to the home country tax rate τ_h, implying that the marginal understock cost is $(1-\tau_h)(p-c)$. Consequently, the expected marginal understock cost is

$$c_u(q, C) = (1-\tau_h)(p-c)(1-G(q)).$$

When the capacity q exceeds the demand D, the pretax profits are $pD - cq$. Three distinct scenarios emerge, depending on the level of D. First, if $pD - cq \le 0$, or equivalently, if $D \le cq/p$, then the division earns no profit and pays no tax. The marginal overstock cost is c. Second, if $pD - cq > 0$ and the resulting tax liabilities $(\tau_h - \tau_l)(pD - cq) \le C$, or equivalently, $D \in (cq/p, C/(p(\tau_h - \tau_l)) + cq/p]$, then the division earns positive profits, and the tax liabilities can be fully offset by the available ECs (C). In this case the local country tax rate τ_l applies to all profits. Similar to the marginal cost analysis for the benchmark model, an overstocked unit incurs a cost c but gains $\tau_l c$ through a tax deduction, resulting in a marginal overstock cost $(1-\tau_l)c$. Third, if $pD - cq > 0$ and $(\tau_h - \tau_l)(pD - cq) > C$, or equivalently, $D \in (C/(p(\tau_h - \tau_l)) + cq/p, q)$, then the division earns positive profits, and the ECs are insufficient to fully offset the tax liabilities. In this case the home tax rate τ_h applies to the marginal profit, and thus the marginal overstock cost is $(1-\tau_h)c$. Combining these three scenarios, the expected marginal overstock cost is

$$\begin{aligned} c_o(q, C) = {}& cG(cq/p) + c(1-\tau_l) \\ &\cdot \big(G(C/(p(\tau_h - \tau_l)) + cq/p) - G(cq/p)\big) \\ &+ c(1-\tau_h)\big(G(q) - G(C/(p(\tau_h - \tau_l)) + cq/p)\big). \end{aligned}$$

Let $q_2(C)$ be the critical quantity at which the expected marginal overstock costs equal understock costs. That is, $q_2(C)$ is the solution to equation $c_u(q, C) = c_o(q, C)$. We conclude that if the optimal capacity falls into Region L, then $q^*(C) = q_2(C)$. Under what conditions does $q_2(C)$ exist in Region L (i.e., $q_2(C) > q_1(C)$)? To answer this question, let $\hat{q}$ be the solution to the equation

$$\begin{aligned} &cG(cq/p) + c(1-\tau_l)(G(q) - G(cq/p)) \\ &\quad = (p-c)(1-\tau_h)(1-G(q)) \end{aligned}$$

and define $\hat{C} = (p-c)(\tau_h - \tau_l)\hat{q}$. We can verify that $q_1(\hat{C}) = \hat{q}$ and $q_2(\hat{C}) = \hat{q}$, implying that $q_1(\hat{C}) = q_2(\hat{C})$. With the additional observation from the definition that $q_1(C)$ increases in C and $q_2(C)$ (if it exists) decreases in C (because $c_o(q, C)$ is increasing in C, but $c_u(q, C)$ is invariant to C), we conclude that for any $C < \hat{C}$

$$q_2(C) > q_2(\hat{C}) = q_1(\hat{C}) > q_1(C).$$

These arguments lead to the following proposition.

Proposition 3. *The firm's optimal capacity $q^*(C)$ lies in Region L if and only if $C < \hat{C}$. When it does, $q^*(C) = q_2(C)$.*

Proposition 3 implies that if the ECs are sufficiently low ($C < \hat{C}$), then the global tax consideration transforms the global firm's capacity decision problem into one with three distinct tax rates: τ_l, τ_h, and 0, depending on the realization of the demand. Specifically, the higher tax rate τ_h applies to any marginal gain when understock occurs because the tax liabilities exceed the available ECs. When overstock occurs, as the realized demand increases, the tax rate applied to the marginal profit changes from 0 to τ_l and then to τ_h as the division's profits increase from negative to positive or, equivalently, as the tax liabilities increase from zero to an amount below C, and then to an amount above C.

5.1.3. Region M: $q = q_1(C)$. When the conditions in Propositions 2 and 3 do not hold (i.e., $C \in [\hat{C}, \bar{C}]$), the optimal capacity can only lie in Region M. We summarize this assertion in the following proposition, which completes the characterization of $q^*(C)$.

Proposition 4. *The firm's optimal capacity $q^*(C)$ lies in Region M if and only if $C \in [\hat{C}, \bar{C}]$. When it does, $q^*(C) = q_1(C)$.*

5.2. Properties of Optimal Capacity Decision

In this section we investigate how the firm's optimal capacity decision responds to a change in the firm's business environments. Specifically, we study how three groups of factors—the available ECs C, the profit margin $p - c$, and the tax rates τ_h and τ_l—that are the main drivers of the MNF's global after-tax profitability affect the optimal capacity decision. The following proposition, which describes the impacts of C on the optimal capacity decision, follows directly from the analysis in the previous subsection.

Proposition 5. *As C increases over $[0, \hat{C}]$, $q^*(C) = q_2(C)$ decreases from $q^o(\tau_h)$ to $\hat{q}$; as C increases over $[\hat{C}, \bar{C}]$, $q^*(C) = q_1(C)$ increases from $\hat{q}$ to $q^o(\tau_l)$ at a constant rate $1/((\tau_h - \tau_l)(p-c))$; as C increases over $[\bar{C}, +\infty)$, $q^*(C)$ stays unchanged at $q^o(\tau_l)$.*

When $C = 0$, no tax cross-crediting is possible and the firm needs to be concerned only with the tax asymmetry effect. Thus, the optimal quantity $q^*(C)$ is $q^o(\tau_h)$, the optimal quantity that maximizes the expected after-tax profits with tax rate τ_h. Intuitively, as C increases, the pretax profits generated from the division should become more valuable for the global firm because more of the resulting tax liabilities owed to the home country can be offset by the increased ECs. However, Proposition 5 indicates that this enhanced value of pretax profits does not necessarily mean that the firm should be more aggressive in its capacity decision. Instead, the optimal capacity decreases in C when C is small ($C \in [0, \hat{C}]$).

This result can be explained as follows. For a small value of C, the optimal capacity lies in Region L so that the tax liabilities in the event of stockout (i.e., $D > q$) are more than enough to fully redeem the ECs. Thus, an increase of C does not affect the marginal understock cost. However, the earlier marginal cost analysis in Region L indicates that an increase of C expands the regime of demand realization under which the ECs would not be fully used but shrinks the regime of demand realization under which the ECs are fully used. Note that the marginal overstock cost in these two regimes is $(1-\tau_l)c$ and $(1-\tau_h)c$, respectively. Hence, an increase of C drives up the overstock cost but does not affect the understock cost, thereby pushing the optimal capacity downward.

When ECs are within a modest range (i.e., $C \in [\hat{C}, \bar{C}]$), Proposition 5 suggests that the global firm's optimal capacity decision is extremely simple: Produce an amount so that the maximum tax liabilities that the division can possibly generate (in the event of stockout) match exactly the ECs C. Interestingly, this optimal capacity is independent of the demand distribution. This finding is in stark contrast to the well-known result from the classical newsvendor model stating that knowledge about the demand distribution is crucial in making optimal capacity decisions. Furthermore, note that with fixed τ_h, $\bar{C} - \hat{C}$ increases as τ_l decreases. Thus, the simple capacity decision is more likely to be optimal when the two tax rates are further apart from each other.

When C becomes sufficiently large (i.e., $C \geq \bar{C}$), more ECs have no effect on the optimal capacity because the tax liabilities generated from any demand realization can be fully offset by the ECs. Thus, all incomes enjoy the lower tax rate τ_l, so $q^*(C) = q^o(\tau_l)$.

For a given $C > 0$, we now turn to the sensitivity of the optimal capacity $q^*(C)$ with respect to a change in the profit margin $p - c$.

Proposition 6. *With fixed c, as the retail price p increases from c to $+\infty$, $q^*(C)$ first increases, then decreases, and finally increases.*

Note that for a fixed c, as p increases from c to $+\infty$, the profit margin $p - c$ increases from 0 to $+\infty$. Conventional wisdom suggests that such a steady increase of the profit margin leads to a monotonic increase of the optimal capacity. Proposition 6 shows that this intuition, true for the traditional newsvendor model and even for the benchmark model studied in §4 (see Proposition 1), is no longer valid for the model that includes tax cross-crediting considerations. This counterintuitive result can be explained as follows. As the profit margin increases, all else being equal, the division's pretax profits improve and the resulting tax liabilities increase. Thus, the increase in the profit margin has the opposite effect on the optimal capacity as that of the increase in ECs. As a mirror image of the result that the optimal capacity increases in C for a modest range of C values in $[\hat{C}, \bar{C}]$, Proposition 6 indicates that as the profit margin increases from 0, the optimal capacity $q^*(C)$ will at some point fall in Region M. As suggested by Proposition 4, the global firm sources the quantity within this region, with the goal of fully redeeming the given ECs C in the event of stockout. As the profit margin continues to increase, a smaller capacity is needed to accomplish this goal.

For a fixed p, the effect on the optimal capacity to a decrease in c or an increase in $p - c$ is similar to the result in Proposition 6, except that the possible change of c is between 0 and p. Thus, for a sufficiently large fixed p, a decrease in c from p to 0 causes $q^*(C)$ to first increase, then decrease, and finally increase.

Next, we examine the effect of a change in the tax rates, τ_l or τ_h, on the optimal capacity decision. We observe that for a large C, the optimal capacity $q^*(C) = q^o(\tau_l)$, which is decreasing in τ_l but is independent of τ_h. For a modest C, $q^*(C) = C/((p-c)(\tau_h - \tau_l))$, which decreases as τ_h increases or as τ_l decreases. For a small C, $q^*(C)$ is nonmonotonic in τ_l or τ_h: it can either increase or decrease as any of the tax rates increases.

In particular, one possibility is that $q^*(C)$ might increase as τ_l increases—a result that is counterintuitive and distinct from the benchmark model presented in §4. The intuition is as follows. Recall from our discussion of Region L in §5.1 that for a small

C, as τ_l increases, the ECs are more likely to be fully used in the event of overstock, resulting in a greater chance of incurring the lower marginal overstock cost $(1-\tau_h)c$. Therefore, the tax cross-crediting effect tends to move the capacity upward as τ_l increases. However, as in the benchmark model, the loss-of-profit-margin effect moves the capacity downward as τ_l increases. When the tax cross-crediting effect dominates the loss-of-profit-margin effect, the optimal capacity increases as τ_l increases.

6. Managerial Tax Rates

Most MNFs prefer to delegate local capacity decisions to local business units through certain decentralized control mechanisms using pretax or after-tax performance measures (see, e.g., Wilson 1993, Phillips 2003). These MNFs would be interested in designing a performance measure to induce local capacity decisions that maximize the global firms' expected worldwide after-tax profits. However, according to Wilson (1993), one of the challenges is in determining a "correct tax rate" for setting after-tax performance measures. In the context of our modeling framework, we assume that the global firm evaluates the subsidiary's performance using an expected after-tax profit maximization measure with a *managerial tax rate* $\hat{\tau}$, which may or may not be the same as the division's local tax rate. We first characterize the optimal managerial tax rate and then discuss the effectiveness of a few simpler pretax and after-tax measures.

Recall from discussions of the benchmark model in §4 that for a managerial tax rate $\hat{\tau}$, the division's best capacity is $q^o(\hat{\tau})$. Because $q^o(\hat{\tau})$ decreases in $\hat{\tau}$, the inverse function $q^{-1}(\cdot)$ is well defined. Thus, internally communicating to the division the optimal managerial tax rate $\hat{\tau}^*(C) \equiv q^{-1}(q^*(C))$ allows the capacity that the division manager chooses to maximize the division's "after-tax incomes" based on the benchmark model to coincide with the globally optimal capacity $q^*(C)$. The following results follow immediately from Proposition 5.

Proposition 7. *For $C=0$, $\hat{\tau}^*(C)=\tau_h$; for $C\in[0,\hat{C}]$, $\hat{\tau}^*(C)$ increases in C; for $C\in[\hat{C},\bar{C}]$, $\hat{\tau}^*(C)$ decreases in C; for $C\geq\bar{C}$, $\hat{\tau}^*(C)=\tau_l$.*

For every dollar of pretax profits generated by the division, the division pays τ_l local taxes, which generate $\tau_h-\tau_l$ tax liabilities that can be partially or fully offset by ECs. So the *effective tax rate* (defined as the ratio of total tax expense to pretax income) falls somewhere between τ_h and τ_l. Thus, because of tax cross-crediting, one may expect that the optimal managerial tax rate should fall somewhere between τ_l and τ_h. However, Proposition 7 implies that the optimal managerial tax rate $\hat{\tau}^*(C)$ could be set even higher than the home country tax rate τ_h. This result suggests that in designing the optimal managerial tax rate for the division, the firm ought not to look for the effective tax rate that reflects the after-tax contribution of the division's pretax incomes. Instead, the global firm might even need to impose a managerial tax rate that is higher than the home country tax rate, which is already high compared with the local tax rate.

The difficulty of determining the "correct" managerial tax rates, the concerns over ease of communication, and the fairness are perhaps some of the reasons that many global firms resort to adopting simpler and more intuitive managerial tax rates to facilitate capacity decisions. Of the 209 MNFs surveyed in a study by Phillips (2003), 143 used pretax measures and 66 used after-tax measures to evaluate their division managers' performances. Phillips (2003) further identifies three types of after-tax performance measures used by MNFs in practice. The first type extensively allocates the company's total tax liabilities among business units. Our optimal managerial rate might serve well in such an active coordination scheme. The second type attributes only local taxes to a local division. Setting the managerial tax rate to the local tax rate would be a good measure. The third type uses a company-wide percentage (e.g., effective tax rate) to allocate tax expenses among business units. In our problem, the effective tax rate for the low-tax division is between the two tax rates τ_h and τ_l. In particular, when the tax liabilities generated by the division are more than enough to redeem the available ECs, the effective tax rate for the division is the home country tax rate τ_h.

Based on this discussion, we investigate in the remainder of this section the effectiveness of the three easily implementable performance measures—namely, the pretax measure (which sets the managerial tax rate to zero) and the two after-tax measures using the local tax rate τ_l and the home country tax rate τ_h, respectively. Recall that the division's optimal capacity decisions are $q^o(0)$, $q^o(\tau_l)$, and $q^o(\tau_h)$, respectively, under these three measures. Because the tax asymmetry effect becomes more salient as the tax rate increases, $q^o(0)\geq q^o(\tau_l)\geq q^o(\tau_h)$ (see Proposition 1). Let Π_0, Π_l, and Π_h be the corresponding expected after-tax profits of the global firm—that is, $\Pi_0=\Pi(q^o(0),C)$, $\Pi_l=\Pi(q^o(\tau_l),C)$, and $\Pi_h=\Pi(q^o(\tau_h),C)$, where $\Pi(q,C)$ is defined in Equation (2) in §3.

Proposition 8. *There exists a threshold $\tilde{C}\in[\hat{C},\bar{C}]$ such that $\Pi_h\geq\Pi_l\geq\Pi_0$ for $C\in[0,\tilde{C}]$ and $\Pi_l\geq\max\{\Pi_h,\Pi_0\}$ for $C\geq\tilde{C}$.*

Several observations are noteworthy. First, the pretax measure is dominated by the other two after-tax measures. Second, if the ECs are less than a threshold value, then the after-home–country-tax measure is the best; otherwise, the after-local-tax measure prevails. By Proposition 5, when C is small ($C \in [0, \hat{C}]$), the firm's optimal capacity is even lower than $q^o(\tau_h)$, which is the smallest quantity among those induced by the three measures discussed above. Thus, all of the three measures lead to overstocking in the capacity decision, but the extent of overstocking is ascending in the order of after-home–country-tax, after-local-tax, and pretax measures. Consequently, the after-home–country-tax measure is the best, whereas the pretax measure is the worst. However, once C exceeds $\hat{C}$, the firm's optimal capacity increases as C increases. That is, it will exceed $q^o(\tau_h)$ and approach $q^o(\tau_l)$, where the after-home–country-tax measure leads to understocking and the other two measures result in overstocking in the division's capacity decision. As C continues to increase, the extent of the understocking under the after-home–country-tax measure becomes more pronounced. Because the after-local-tax measure ends up stocking more than the after-home–country-tax measure, the former performs better than the latter.

Based on results from Propositions 7 and 8, we can make the following suggestions to an MNF that uses a managerial tax rate to coordinate the capacity decisions at its high-tax division. When the available ECs are low and the global firm therefore anticipates that its tax liabilities will exceed ECs, allowing the division to maximize its own after-home–country-tax profits is an effective measure. However, because the home country tax rate τ_h prompts the division's manager to stock more than the optimal quantity, the global firm might consider making some additional downward adjustments of the division's inventory. Such adjustments should become more aggressive as C increases.

On the other extreme, when the given ECs are sufficiently high and are expected to be more than the tax liabilities generated at the low-tax division, the parent company should use its local tax rate to evaluate the division's after-tax profitability. Similarly, because such a policy tends to induce the division manager to stock more than the optimal quantity, additional downward adjustment should be made to compensate for the suboptimality; such adjustments should be increasingly less aggressive as C increases.

When C approaches the threshold value $\tilde{C}$, neither policy (based on τ_l or τ_h) works very well without proper adjustments, suggesting that heavier coordination efforts are needed or even that the optimal managerial tax rate should be adopted.

7. Robustness Results

In this section we discuss a number of extensions of our base model. In §7.1 we generalize the newsvendor profit function in the base model to a general profit function that satisfies several mild and reasonable assumptions. In §7.2 we relax the assumption that the leftover ECs have zero salvage value by considering the single-period setting with exogenous (positive) value of leftover ECs and then the multiperiod setting with endogenous value of leftover ECs, allowing both carryback and carryforward of ECs. Similar conclusions hold for the loss carryback and carryforward. In §7.3 we extend our single-division problem with exogenous ECs to a two-division problem where the ECs are endogenously determined by the profits generated from the division in the high-tax country.

7.1. General Profit Function

This section generalizes the newsvendor profit function to a general profit function. We show that almost all results and insights established earlier for the base model still hold under this general model, demonstrating that these results and their implied managerial insights are not driven by the newsvendor profit function. However, our analysis in this section shows that the marginal cost analysis in §5 is no longer effective for the generalized problem with a general profit function. A new set of technically nontrivial analyses, along with some new insights, are developed.

Consider a general function $R(Q, S)$, where Q is the capacity and S represents the uncertain market condition. Let s be the realized value of S. Let $R_1(Q, s) = \partial R(Q, s)/\partial Q$; $R_{11}(Q, s) = \partial^2 R(Q, s)/\partial Q^2$; $R_{12}(Q, s) = \partial^2 R(Q, s)/\partial Q \partial s$; and $R_2(Q, s) = \partial R(Q, s)/\partial s$. We make the following mild assumptions.

(A1): $R(Q, s)$ is concave in Q for any $s \in [\underline{s}, \bar{s}]$, i.e., $R_{11}(Q, s) \le 0$;

(A2): $R(Q, s)$ has increasing difference in Q and s, i.e., $R_{12}(Q, s) \ge 0$;

(A3): $R(Q, s)$ increases in s (i.e., $R_2(Q, s) \ge 0$);

(A4): $R(0, s) = 0$ for any $s \in [\underline{s}, \bar{s}]$; and

(A5): $R(Q, \underline{s}) \le 0$ for any $Q \ge 0$.

We can rewrite the objective function of our base model in §3 as

$$\Pi(Q) = E_S\big[\min(R(Q, S) - \tau_l R^+(Q, S), \\ R(Q, S) - \tau_h R^+(Q, S) + C)\big]. \qquad (5)$$

The global firm's optimal capacity decision is $Q^* = \arg\max_Q \Pi(Q)$.

As implied by (5), $\Pi(Q)$ is bounded above by $E_S[R(Q, S) - \tau_l R^+(Q, S)]$ for any Q. Therefore, assumption (A1) implies that $E_S[R(Q^o(\tau_l), S) - \tau_l R^+(Q^o(\tau_l), S)]$ is an upper bound on $\Pi(Q)$ for any Q, where $Q^o(\tau) = \arg\max_Q E_S[R(Q, S) - \tau R^+(Q, S)]$. We define $\mathscr{C} = (\tau_h - \tau_l) R^+(Q^o(\tau_l), \bar{s})$. If $C \ge \mathscr{C}$, then assumption (A3) suggests that the tax liabilities, $(\tau_h - \tau_l) R^+(Q^o(\tau_l), s)$, that are generated by the division under the capacity $Q^o(\tau_l)$ never exceed C for any realization s. Hence,

$\Pi(Q^o(\tau_l)) = E_S[R(Q^o(\tau_l), S) - \tau_l R^+(Q^o(\tau_h), S)]$, attaining the upper bound of $\Pi(Q)$. This leads to the following result.

Lemma 1. *If $C \geq \bar{\mathscr{C}}$, then the optimal capacity that maximizes the global firm's expected after-tax profits is $Q^* = Q^o(\tau_l)$.*

Now we turn to the case in which $C < \bar{\mathscr{C}}$. We first summarize a property of the optimal capacity Q^*.

Lemma 2. *If $C < \bar{\mathscr{C}}$, then $(\tau_h - \tau_l)R^+(Q^*, \bar{s}) \geq C$.*

By Lemma 2, without loss of generality, we can focus on the set of Q that satisfies $(\tau_h - \tau_l) \cdot R^+(Q, \bar{s}) \geq C$. Thus, $R^+(Q, \underline{s}) = 0$ (see (A5)) and the monotonically increasing property of $R(Q, s)$ in s (see (A3)) yield the result that for any Q satisfying $(\tau_h - \tau_l)R^+(Q, \bar{s}) \geq C$, there exists a cutoff value of the realized market condition $s \in [\underline{s}, \bar{s}]$ under which the tax liabilities generated at $S = s$ equal the ECs C (i.e., $(\tau_h - \tau_l)R^+(Q, s) = C$). Further, for $S < s$, the tax liabilities are not enough to fully redeem the ECs, so the firm's after-tax profits are $R(Q, s) - \tau_l R^+(Q, s)$. For $S > s$, the tax liabilities generated exceed the ECs, so the firm's after-tax profits are $R(Q, s) - \tau_h R^+(Q, s) + C$. Hence, the global firm's capacity investment problem can be rewritten as $\max_Q J(Q, s(Q))$, where for $s \in [\underline{s}, \bar{s}]$,

$$J(Q, s) \equiv \int_{\underline{s}}^{s} [R(Q, x) - \tau_h R^+(Q, x) + C] g(x)\, dx + \int_{s}^{\bar{s}} [R(Q, x) - \tau_l R^+(Q, x)] g(x)\, dx,$$

and $s(Q)$ satisfies

$$(\tau_h - \tau_l)R^+(Q, s(Q)) = C.$$

Let $\tilde{Q}(s) = \arg\max_Q J(Q, s)$ for $s \in [\underline{s}, \bar{s}]$, where the minimum is chosen in the case of multiple maximizers. Finally, for a given $C \geq 0$, let $s^*(C) = \min\{s \mid (\tau_h - \tau_l)R(\tilde{Q}(s), s) = C\}$. We now characterize the optimal capacity decision Q^* in terms of $\tilde{Q}(\cdot)$.

Proposition 9. *For $C = 0$, $Q^* = Q^o(\tau_h)$; for $C \in [0, \hat{\mathscr{C}}]$, $Q^* = \tilde{Q}(s^*(C))$; and for $C \geq \bar{\mathscr{C}}$, $Q^* = Q^o(\tau_l)$.*

From Proposition 9, we see that the optimal capacity decision Q^* under tax cross-crediting with given ECs (C) maximizes the weighted average of two types of income, which, if positive, are taxed at two distinct tax rates of τ_h and τ_l, respectively. Specifically, when $C = 0$, no tax cross-crediting is possible; the firm needs to concern itself only with the tax asymmetry effect. Thus, the optimal quantity Q^* is $Q^o(\tau_h)$—the optimal quantity that maximizes the expected after-tax profits with tax rate τ_h. As C increases, the incomes generated under market conditions $s \in (0, s^*(C)]$, which are taxed at the home country tax rate τ_h, carry increasing weight in the firm's overall expected after-tax profits.

We define $\hat{Q}(s) = \arg\max_Q R(Q, s)$ for $s \in [\underline{s}, \bar{s}]$. Although the optimal capacity decision needs to be made ex ante (i.e., before observing the market condition), the ex post optimal capacity $\hat{Q}(s)$ can be seen as the ideal capacity under a certain market condition s.

Lemma 3. *The ex post optimal capacity* (a) *$\hat{Q}(s)$ increases in s;*
(b) *there exists $s_1 \in [\underline{s}, \bar{s}]$ such that $\hat{Q}(s_1) = \tilde{Q}(s_1)$;*
(c) *$\hat{Q}(s) < \tilde{Q}(s)$ for $s < s_1$, and $\hat{Q}(s) \geq \tilde{Q}(s)$ for $s \geq s_1$.*

Let s_1 be the minimum solution that satisfies $\tilde{Q}(s_1) = \hat{Q}(s_1)$, and define $\hat{\mathscr{C}} = (\tau_h - \tau_l)R(\tilde{Q}(s_1), s_1)$. We then have the following proposition:

Proposition 10. *The optimal capacity $Q^* = \tilde{Q}(s^*(C))$ decreases from $Q^o(\tau_h)$ in C for $C \in [0, \hat{\mathscr{C}}]$ and then increases to $Q^o(\tau_l)$ in C for $C \in [\hat{\mathscr{C}}, \bar{\mathscr{C}}]$.*

Recall in our earlier discussion that the income generated under a group of market conditions $s \in (0, s^*(C)]$ is taxed at the local tax rate τ_l. As the firm's ECs increase incrementally from C to $C + \Delta$, this group of lower-taxed market conditions, denoted as $\Omega(C) \equiv (0, s^*(C)]$, expands to $\Omega(C + \Delta)$. We first observe from Lemma 3 that if $s^*(C) < s_1$, then $\hat{Q}(s^*(C)) < \tilde{Q}(s^*(C))$. Thus, as C increases from zero incrementally, we expect $\hat{Q}(s) < \tilde{Q}(s^*(C))$ for any market condition $s \in (C, C + \Delta]$ that emerges in the expanded group. In other words, the ideal capacity levels for these newly emerged market conditions are lower than the original optimal capacity level $\tilde{Q}(s^*(C))$.

We observe further that the marginal after-tax profit is higher under the newly emerged market conditions $s \in (C, C + \Delta]$ when compared with those outside the group $\Omega(C + \Delta)$. Therefore, when deciding the optimal capacity that maximizes its expected after-tax profits, the firm should respond more favorably to these newly emerged market conditions. That is, the optimal capacity should move toward the ideal capacity levels $\hat{Q}(s)$, $s \in (C, C + \Delta]$, which, according to an earlier observation, are lower than $\tilde{Q}(s^*(C))$. As a result, Q^* decreases in C for $C \in [0, \hat{\mathscr{C}}]$.

However, once the ECs, C, exceed the threshold $\hat{\mathscr{C}}$, any further increase of C expands the lower-taxed group of market conditions beyond s_1. In other words, we have $s > s_1$ and, based on earlier observation, $\hat{Q}(s) > \tilde{Q}(s^*(C))$ for all $s \in (C, C + \Delta]$. Thus, the incremental increase of C pushes the optimal capacity level upward toward the ideal capacity level for newly emerged market conditions in the expanded lower-taxed group. Consequently, Q^* increases in C for $C \in [\hat{\mathscr{C}}, \bar{\mathscr{C}}]$.

When C reaches $\bar{\mathscr{C}}$, the lower-taxed group $\Omega(C)$ expands to the entire range of market conditions (i.e., $[\underline{s}, \bar{s}]$). As a result, the division's pretax profits are subject to the local tax rate τ_l. Consequently, the optimal quantity Q^* stays at $Q^o(\tau_l)$—the optimal quantity that maximizes the expected after-tax profits with tax rate τ_l.

Finally, all of the results in §6 regarding the effectiveness of the managerial tax rates still hold in the generalized model that includes the general profit function studied in this section.

7.2. Carryback and Carryforward of Loss and Excess Credits

Many countries' tax laws permit businesses to carry their losses and ECs backward or forward for a number of years. For example, according to Section 904(c) of the Internal Revenue Code, the United States permits its MNFs to carry ECs backward for up to one year and forward for up to 10 years. To make our analysis more concise, our base model assumes that the global firm is interested in maximizing its worldwide after-tax earnings within a tax year. Such a performance measure is consistent with the current requirements of the U.S. Generally Accepted Accounting Principles (GAAP) earning report and is used by many companies. For example, Powers et al. (2013) identify 905 firms that pay annual cash bonuses to their CEOs based on after-tax earnings. However, it ignores the effects of possible loss or EC carryback and carryforward. We thus relax this restriction in this section.

Loss and EC carryforwards are considered part of a company's *deferred tax assets* (DTAs). If these DTAs are recognized at their full value in our base model, then the optimal capacity decision is identical to that of the traditional newsvendor model. However, full recognition is not the case in practice because of uncertainties related to the realization of DTAs and their potential loss of value in the future. Because DTAs reflect potential tax savings arising from future tax deductions, GAAP requires that a firm only include DTAs on its balance sheet when it has available evidence to show that this portion of DTAs is more likely than not (a likelihood of more than 50%) to be realized (Petree et al. 1995). Evidence suggests that, in practice, many companies will not be able to use up all their DTAs and therefore tend not to recognize part of their DTAs in their balance sheets on the grounds of managerial prudence. For example, a survey by Cooper and Knittel (2006) finds that over a 10-year window, about 40%–50% of net operating losses—a form of DTAs—is used as a loss carryforward deduction, but 25%–30% is lost (e.g., the firm no longer exists), and the other 10%–20% remains unused.

In what follows, we show the robustness of our main results by studying two distinct approaches to recognizing partial values of DTAs. The first approach, which is aligned with the accounting literature, imposes an exogenous value function to recognize the value of DTAs in a single-period model. The second approach extends the single-period model into a multiperiod model, in which the value of DTAs in each tax year is determined endogenously by solving the MNF's optimal operational decisions in the remaining planning horizon.

7.2.1. Exogenous Value. We discuss two methods suggested in accounting literature to recognize partial values of DTAs in a single period. The first method follows the U.S. Financial Accounting Standards (FAS), which require a company to reduce its DTAs by a certain amount of *valuation allowance* if it faces more than a 50% chance that all or part of the DTAs will not be realized in the future. Following De Waegenaere et al. (2003), we can add to our base model two upper limits, denoted by A and B, for loss and EC carryforwards, respectively. The MNF's objective in this case is to maximize its current year's expected after-tax profits, as well as its carryforward DTAs reported on its balance sheet, per FAS requirements. The objective of our base model can be modified accordingly as follows:

$$\begin{aligned}\Pi(Q, C) = E_S\big[&R(Q, S) - \tau_h R^+(Q, S)\\ &+ \tau_l \min(A, R^-(Q, S))\\ &+ \min(C, (\tau_h - \tau_l)R^+(Q, S))\\ &+ \min(B, [C - (\tau_h - \tau_l)R^+(Q, S)]^+)\big],\end{aligned}$$

where $R^-(Q, S) = -\min(R(Q, S), 0)$.

The second method, which is adopted by Eldor and Zilcha (2002) in their study of tax asymmetry, recognizes the partial value of DTAs through a discount rate. In the context of our study, we will use two discount rates—σ_1 and σ_2 ($0 \le \sigma_1, \sigma_2 < 1$)—for loss and EC carryforwards, respectively. The modified model, which includes the base model as a special case with zero discount rate, is described as follows. The MNF's objective function now becomes

$$\begin{aligned}\Pi(Q, C) = E_S\big[&R(Q, S) - \tau_h R^+(Q, S) + \sigma_1 \tau_l R^-(Q, S)\\ &+ \min(C, (\tau_h - \tau_l)R^+(Q, S))\\ &+ \sigma_2[C - (\tau_h - \tau_l)R^+(Q, S)]^+\big].\end{aligned}$$

The same analysis developed in the previous section can be used to show that Propositions 9 and 10 continue to hold for the optimal capacity under both methods.

7.2.2. Endogenous Value. We extend our single-period model to a dynamic multiperiod model where the value of leftover ECs is determined endogenously by solving the MNF's operational problem in the remaining time periods. For expositional simplicity, we focus only on the carryback and carryforward of ECs and note that loss carryback and carryforward can be incorporated into the model without loss of generality.

Consider a planning horizon consisting of T time periods. Let C_n be the ECs newly arising in period n for $n = 1, 2, \ldots, T$. We assume the tax rates/rules do not change during the planning horizon. The sequence of events in period n is as follows. First, the leftover ECs in the previous period are carried over to period n. We assume that all of the leftover ECs are eligible to offset the tax liabilities generated in period n. This assumption holds if the entire planning horizon is short relative to the maximum amount of carryforward time for ECs (which is 10 years). Naturally, the ECs, C_n, newly arising in period n, are also eligible. Because any ECs can be carried back to, at most, one immediately preceding tax year, the ECs, C_{n+1}, generated in period $n+1$—but not those ECs generated after period $n+1$—should also be counted in the total ECs that are eligible to offset the tax liability generated in period n. We denote the total ECs (i.e., the sum of the three types of aforementioned ECs that are eligible for offsetting the tax liabilities in the current period n) by C. Second, after observing C, the MNF decides the capacity Q. Third, the market condition S_n is realized, resulting in pretax profits $R(Q, S_n)$ and tax liabilities $(\tau_h - \tau_l)R^+(Q, S_n)$ which are offset up to C. Because the possibility exists that any unit of EC, if carried over into the future period, might not be redeemed because of insufficient tax liabilities, redeeming it in the earliest time always produces higher value than carrying it forward for future use. Therefore, the optimal move for the global firm is to redeem the ECs as early as possible. Consequently, the total ECs that are eligible to offset the tax liability in period $n+1$ become $(C - (\tau_h - \tau_l)R^+(Q, S_n))^+ + C_{n+2}$, where the ECs, C_{n+1}, newly arising in period $n+1$ are already counted into C by first completely carrying C_{n+1} back to period n and then carrying any unused ECs forward to period $n+1$. This approach allows us to formulate the MNF's capacity problem as the following dynamic programming problem:

$$\begin{aligned} V_n(C) = \max_Q E_{S_n, C_{n+2}}\big[&R(Q, S_n) - \tau_l R^+(Q, S_n) \\ &- \big((\tau_h - \tau_l)R^+(Q, S_n) - C\big)^+ \\ &+ V_{n+1}\big((C - (\tau_h - \tau_l)R^+(Q, S_n))^+ + C_{n+2}\big)\big], \end{aligned}$$

for $n = 1, 2, \ldots, T$, where $V_n(C)$ is the MNF's optimal total expected after-tax profits from period n onward, given that the total ECs that are eligible to offset the tax liabilities in period n are equal to C. Let $Q_n^*(C)$ be the maximizer. Instead of assuming an exogenous value for leftover ECs, as in our single-period model, the multiperiod model allows the value of leftover ECs in every period to be endogenously determined by solving the MNF's optimal capacity problem in the remaining periods.

We make two mild and reasonable assumptions. First, the per-period profit function $R(\cdot, \cdot)$ satisfies (A1)–(A5). Second, the end-of-horizon salvage value function (i.e., $V_{T+1}(C)$) is a concave increasing function, and $V'_{T+1}(C) \in [0, 1]$ for any $C \geq 0$. The concavity property implies the diminishing return of ECs, and the assumption $V'_{T+1}(C) \in [0, 1]$ implies that any unit of excess credit is always valuable, but its value is no more than 1 because of the possibility that the firm will not have sufficient tax liability to offset in the future.

Lemma 4. *$V_n(C)$ is a concave increasing function and $V'_n(C) \in [0, 1]$ for any $C \geq 0$ and $n = 1, 2, \ldots, T$.*

This lemma implies that the two properties—the diminishing return property and the marginal value of ECs being bounded above by 1, which we have imposed to the end-of-horizon salvage value function as an intuitively appealing assumption—are preserved for the endogenously determined optimal value function of any given ECs in every period n.

Proposition 11. *There exist thresholds $\hat{C}_n$ such that the optimal capacity $Q_n^*(C)$ decreases in C for $C \in [0, \hat{C}_n]$ for all $n = 1, 2, \ldots, T$. Further, $\hat{C}_n \geq \hat{C}$.*

This proposition implies that the nonintuitive result (i.e., the optimal capacity decreases in ECs when it is small) is robust in the multiperiod model with carryback and carryforward of ECs. Further, the result that $\hat{C}_n \geq \hat{C}$ indicates that the range of small ECs is expanded by considering the endogenous value of leftover ECs resulting from the EC carryback and carryforward.

7.3. Endogenous Repatriation Decisions

In this subsection, we work with the dynamic multiperiod model but relax the assumption that the profits of the low-tax division must be repatriated back to the home country in the same period as when they are generated.

Instead of assuming full repatriation, the MNF decides the amount of profits to repatriate from the low-tax division back to the home country, while delaying the repatriation of the remaining profits to future periods. The MNF might benefit from such deferred repatriation, which includes potential gains from possible future tax amnesty, such as the one that occurred in 2004 (reducing the corporate tax rate from 35% to 5.25%). To capture such potential benefits, we introduce a discount factor $\theta \in [0, 1]$, such that delaying the payment of tax liabilities X to some future period would cost the MNF only θX (in expectation).

The value of θ reflects the combined effects of the chance for tax amnesty and the size of the tax rate reduction.

Specifically, given the available ECs C and the pretax profits $R(Q, S_n)$ in period n, which results in tax liabilities $(\tau_h - \tau_l)R^+(Q, S_n)$ under the full repatriation, the optimal decision for the MNF is to delay payment of the tax liabilities that cannot be offset by the available ECs (i.e., $((\tau_h - \tau_l)R^+(Q, S_n) - C)^+$) because such delayed tax liabilities would cost the MNF only $\theta((\tau_h - \tau_l)R^+(Q, S_n) - C)^+$ in the future period, in expectation. Under the above optimal repatriation strategy, the MNF's capacity problem can be written as the following dynamic programming problem:

$$\begin{aligned} V_n(C) = \max_Q E_{S_n, C_{n+2}}\big[&R(Q, S_n) - \tau_l R^+(Q, S_n) \\ &- \theta\big((\tau_h - \tau_l)R^+(Q, S_n) - C\big)^+ \\ &+ V_{n+1}\big((C - (\tau_h - \tau_l)R^+(Q, S_n))^+ + C_{n+2}\big)\big], \end{aligned}$$

for $n = 1, 2, \ldots, T$. By using the same proof procedure, we can show that Proposition 11 continues to hold if $\theta > 0$.

To summarize, we show that as long as delaying repatriation does not completely eliminate the cost of tax liabilities, our core result is robust in the multiperiod model with carryback and carryforward of ECs and endogenous repatriation decisions.

7.4. Endogenously Generated ECs

In this section, we consider a situation in which the ECs to be cross-credited by the low-tax division are endogenously generated by another subsidiary of the same MNF from a high-tax foreign country. To differentiate the global firm's two subsidiaries, we use the subscripts l and f to indicate the respective low-tax division and high-tax division. Thus, $\tau_l < \tau_h < \tau_f$. We use a bold font to indicate a vector variable. For an arbitrary capacity decision $\mathbf{q} = (q_l, q_f)$, the global firm's expected worldwide after-tax profits are given by

$$\begin{aligned} &\Pi(\mathbf{q}) \\ &= E_{\mathbf{D}}\bigg[\sum_{i=f}^{l}[R_i(q_i, D_i) - \tau_i R_i(q_i, D_i)^+] - (\tau_h - \tau_l)R_l(q_l, D_l)^+ \\ &\quad + \min((\tau_f - \tau_h)R_f(q_f, D_f)^+, (\tau_h - \tau_l)R_l(q_l, D_l)^+)\bigg], \quad (6) \end{aligned}$$

where the first term of the right-hand side of the equation is the profit repatriated to the home country after paying local taxes, the second term represents the excess limitations from the low-tax subsidiary, and the last term is the amount of excess credits being used to offset the tax liabilities. The objective of the global firm is to maximize its expected worldwide after-tax profits from both subsidiaries.

Note that Equation (6) can be rewritten as

$$\begin{aligned} \Pi(\mathbf{q}) = E_{\mathbf{D}}\big[\min\big(&\Pi_f(\tau_h, q_f) + \Pi_l(\tau_h, q_l), \\ &\Pi_f(\tau_f, q_f) + \Pi_l(\tau_l, q_l)\big)\big], \end{aligned}$$

where for a tax rate τ, $\Pi_i(\tau, q_i) \equiv E_{D_i}[R_i(q_i, D_i) - \tau R_i(q_i, D_i)^+]$, $i = f, l$. Based on Theorem 5.5 in Rockafellar (1970), the pointwise infimum of an arbitrary collection of concave functions is also concave, implying that $\Pi(\cdot)$ is a concave function. Thus, the optimal capacity decisions can be obtained by solving the first-order conditions. The concavity property allows us to demonstrate via a numerical study that the key insights from our base model continue to hold.

Let $\tau_f = 0.45$, $\tau_l = 0.20$, and $\tau_h = 0.35$. The two divisions have the same price/cost parameters: $p_i = 40$, $c_i = 35$, where $i = f$, l, and both face demands with truncated normal distribution. We fix the mean $\mu_l = 50$ and the standard deviation $\sigma_l = 40$ at the low-tax division but vary the mean demand μ_f at the high-tax division from 10 to 135, while keeping its coefficient variation fixed at $\sigma_f / \mu_f = 0.8$.

Note that as μ_f varies from 10 to 135, the global firm's expected available ECs increase accordingly. Figure 1 shows that as μ_f increases, the optimal capacity decision at the low-tax division q_l^* first decreases, then increases, and finally stays flat. This numerical result is consistent with the analytical results in §5.

Turning now to the managerial tax rates, we follow the discussion in §6 by focusing on the three decentralized policies: the pretax measure (setting the managerial tax rate for each subsidiary to zero), the after-local-tax measure (setting the managerial tax rate to the local tax rate τ_f and τ_l for high-tax and low-tax divisions, respectively), and the after-home–country-tax measure (setting the managerial tax rates for both subsidiaries at the home country's tax rate τ_h). We

Figure 1 (Color online) Optimal Capacity at Low-Tax Division

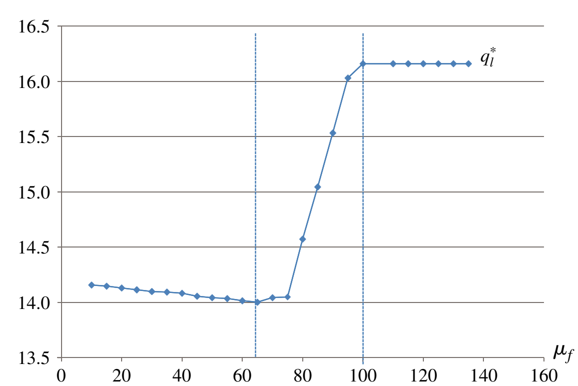
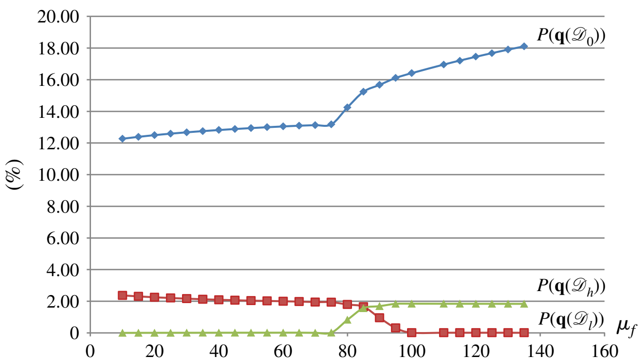


Figure 2 (Color online) Performance of Suboptimal Policies



denote these three policies as $\mathscr{D}_0$, $\mathscr{D}_l$, and $\mathscr{D}_h$, respectively. The corresponding capacity decisions under these policies are $\mathbf{q}(\mathscr{D}_0)$, $\mathbf{q}(\mathscr{D}_l)$, and $\mathbf{q}(\mathscr{D}_h)$. To measure the effectiveness of a capacity decision $\mathbf{q}$, we define $P(\mathbf{q}) \equiv [\Pi(\mathbf{q}^*) - \Pi(\mathbf{q})]/\Pi(\mathbf{q})$.

Figure 2 shows the effectiveness of the three proposed policies as the mean demand μ_f varies from 10 to 135. We first observe that policy $\mathscr{D}_0$ performs poorly because it ignores both tax asymmetry and cross-crediting effects. Policy $\mathscr{D}_h$ performs quite well for small μ_f because the firm has small ECs available for cross-crediting. As μ_f increases beyond 85, $\mathscr{D}_l$ performs much better than $\mathscr{D}_h$. For μ_f between 85 and 90, the ECs and tax liabilities generated by the two subsidiaries are very close to each other; that is, tax liabilities will be nearly cross-credited by all of the available ECs. In this region, both policies $\mathscr{D}_l$ and $\mathscr{D}_h$ perform poorly relative to the centralized decision. These observations are consistent with the analytical results in §6.

We conclude by pointing out two important extensions to the multidivision problem. First, similar to what we have done for the single-division problem, one may extend the single-period setting to a dynamic multiperiod setting to allow carryback and carryforward of ECs. Second, one may allow the unused capacity in one division to be used to satisfy the excess demand from the other division. We leave these extensions for future research.

8. Conclusions

This paper studies global capacity decisions at a subsidiary of a U.S.-based MNF located in a low-tax country. Casting the problem in a newsvendor model that captures the effects of tax asymmetry and cross-crediting in a global business environment, our research demonstrates the importance of integrating international tax planning and global supply chain management decisions.

In particular, our study offers a number of managerial insights on managing global capacity decisions in accordance with FTC planning. Some of these insights are counterintuitive when compared with the conventional understanding of the capacity decisions made without considering tax-related issues. For example, we show that an improvement in a firm's after-tax profitability (through increased ECs, or an increased profit margin, or a reduced tax rate) might induce a division manager to produce less, not more. We also show that the optimal capacity decision under some quite probable circumstances can be made without knowledge of the demand distribution. An interesting future direction is to use MNFs' PPE data to empirically examine the relationship between the MNF's PPE investment decision and parameters such as tax rates, the available ECs, and the product profit margin.

Our study also provides a number of surprising insights into the choice of managerial tax rates in a decentralized decision structure. For example, it suggests that to align a low-tax division's capacity decision with that of the global firm, the parent company might need to use a managerial tax rate that is even higher than the home-country tax rate, and that the two easily implementable after-tax measures with home country tax rate and local tax rate should be used in place of the pretax measure, which is still popular among many MNFs.

We note that although our paper focuses on the study of a low-tax division with given ECs, all of its results and insights still carry over, with some straightforward modifications, to the mirror case, where a high-tax division makes capacity decisions under any given excess limits that result from profit repatriation from low-tax divisions. Therefore, we omit the repetitive analysis of such a case.

Finally, although we focus on studying the effects of tax planning on the MNFs' global capacity decisions, we note that the recent publicity of U.S. corporation inversions has further demonstrated the critical role of tax planning in influencing MNFs' other important strategic decisions, such as location choices for the headquarters and various other business activities.

Supplemental Material

Supplemental material to this paper is available at http://dx.doi.org/10.1287/msom.2015.0526.

Acknowledgments

The authors are grateful to the editor, associate editor, and three referees for their constructive comments. The authors thank Jiawei Zhang for his helpful comments. The second author was supported in part by the Research Grants Council of the Hong Kong Special Administrative Region, China [Project CUHK445710].

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