When should a firm set its selling price to cope with gray market trade?

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Abstract

This study investigates the problem of timing for firms that must cope with gray market in setting its prices by applying an observable delay game. We consider a case in which a multinational firm sells a product in two countries, and a parallel importer buys the product in one country and resells it in the other country. We show that the multinational firm never sets its price at the same time when the parallel importer sets in equilibrium, and that the multinational firm's optimal timing depends on the degree of variation in consumer preferences for product quality.

Keywords: M21, L13, L21

1 Introduction

Gray market trade, also called parallel trade, means that a product protected by a copyright, trademark, or patent is sold in one market, and thereafter legally imported into another market by an entity besides the owner of the original product rights. In the present world economy, gray market trade prevails in various consumer products, including clothing, electronic devices, automobiles, cosmetics, pharmaceuticals, and beauty goods. Although the share of gray market trade varies across products and countries, the existence of a gray market should significantly affect firms' economic performance. A report by EFPIA (2019) estimates the size of gray market trade in the EU drug market in 2017 to be €5,408 million, with the highest market share among EU countries in Denmark (26%). KPMG (2008) reports that losses due to gray market trade amount to $58 billion (8% of global sales) in the information technology industry.

A number of prior studies related to gray market trade have been carried out, as detailed in Section 2. In discussions of gray market trade, not only the impacts of the trade on the economic surplus and profits but also firms' decisions in the presence of a gray market trade command significant attention from both researchers and business practitioners. However, the existing literature neglects the question of when a firm that originally produces a product and faces a gray market should determine its selling price in the gray market, despite this being an important practical problem for many firms that cope with gray market activities[1].

Consequently, this study examines the timing problem for when firms confronting the gray market should set their selling prices, using an observable delay game framework developed in game theory studies (e.g. Hamilton and Slutsky, 1990; van Damme and Hurkens, 1996, 1999, 2004). Specifically, we consider a situation in which a multinational firm (MNF) produces a specific product and distributes it in two countries through its own authorized channel and a parallel importer (PI) buys a some amount of the product in one country and resells it in the other country through an unauthorized channel. We assume vertical product differentiation between the products sold by the MNF and PI because consumers evaluate a genuine product sold by the MNF through the authorized channel more highly than a product sold by the PI through the unauthorized channel. Moreover, we assume that consumers have different preferences for product quality. Our model assumes that the MNF and PI endogenously choose not only the selling price but also the timing of pricing to investigate the problem of when these firms should set their selling prices.

The central findings in this paper are as follows: a subgame perfect Nash equilibrium[2], in which the MNF and PI set their prices in the gray market at the same time never occurs and two types of equilibrium can occur depending on the degree preference for the product quality of consumers in the market in which the MNF faces gray market trade. On the one hand, when the difference in consumer preference for product quality is small, the MNF always sets its price sold

[1] Li et al. (2018) investigate the impact of the power structure (decision making order) between an authorized retailer and third-party parallel importer on market outcomes but do not provide an analysis regarding the appropriate timing of decision making for firms facing gray market trade.

[2] In this study, each firm (MNF, PI) simultaneously announces the timing of its pricing in Stage 1. Then, in Stage 2, they set their prices according to the announced timing. Even if the decision making in Stage 2 is sequential, as in the Stackelberg leadership game, this study uses "subgame perfect Nash equilibrium" because the decision making in Stage 1 is simultaneous.

in the gray market before the PI sets the price. On the other hand, when the difference in consumer preference in the market with parallel imports is large, the MNF sets the price in the gray market after the PI sets its price in equilibrium. In addition, the MNF can earn a higher profit by setting its price later when the difference is large.

Our results provide managerial implications for firms facing gray market trade. Firms that confront gray market trade should keep a close eye on consumer preferences for products offered by gray market trade and use third-party importers to increase their own profits according to those preferences. Specifically, if the consumers recognize that the difference between the firms' products and gray market products is small, firms can improve their profits by setting prices before third-party importers. This is because the price setting ahead allows third-party importers to increase their sales in the gray market, thereby, increasing their sales volume in the non-gray market. However, if the consumers experience a large difference between their products and the gray market products, firms can improve their profits by setting prices after the third-party importers. This is because later pricing can discourage the activities of third-party importers and increase sales in the gray market.

Our model structure is closely related to those of Li (2014) and Matsui (2017) in that the pricing timing decisions by firms are endogenously determined. Li (2014) investigates the timing problem when two vertically differentiated firms should set their own prices. He shows that a sequential equilibrium (a high-quality firm sets its price earlier than a low-quality firm) is risk dominant. Matsui (2017) investigates the timing problem when a manufacturer managing dual-channel supply chains should set prices. He shows that simultaneous price competition between a manufacturer and a retailer never occurs in equilibrium, and that the manufacturer should post the direct price before or upon, but not after, setting the wholesale price for the retailer. Our result differs from those of Li (2014) and Matsui (2017) in that we show that setting a selling price later can improve the firm's profit. This result is new and thus contributes to the existing literature.

The remainder of this paper proceeds as follows. Section 2 reviews the literature on gray market trade. Section 3 presents the basic assumptions and settings of our economic model. In Section 4, we analyze a non-cooperative game model and derive an subgame perfect Nash equilibrium as well as present the operational implications. Section 5 concludes.

2 Literature review

Many previous studies of gray market trade focus on its impacts on the economic surplus and profits, pointing out the various circumstances in which a complete ban of gray market trade negatively affects economic outcomes. Bucklin (1993), Malueg and Schwartz (1994), Richardson (2002), Maskus and Chen (2004), Valletti and Szymanski (2006), and Matsui (2014) focus on the effect of gray market trade on the economic surplus. Bucklin (1993) constructs an economic model to identify the effect of gray market trade. He finds that the loss from gray market trade is insufficient to justify restriction by public agencies, which may complicate supply chain management. Malueg and Schwartz (1994) point out that gray market trade prevents a manufacturer from price discrimination for the same goods between markets, but that setting a uniform price increases the price and thus has the converse effect of damaging social welfare. Maskus and Chen (2004) theoretically and empirically show that it is possible to reduce the global social surplus by fully restricting gray market trade. Richardson (2002), Valletti and Szymanski (2006), and Matsui (2014) also show that gray market trade has positive impacts on the social surplus.

Studies that focus on manufacturers' profits overall indicate that manufacturers should tolerate some level of gray market trade (e.g. Dutta et al., 1994; Ahmadi and Yang, 2000; Maskus and Chen, 2002; Xiao et al., 2011; Ahmadi et al., 2015, 2017; Iravani et al., 2016). Ahmadi and Yang (2000) investigate gray market trade when customers are segmented in an importing country. In their model, gray market trade works as another channel for genuine products and creates a third and new segment of consumers who would not have previously bought this product because of price discrimination. Eventually, gray market trade may help the original manufacturer expand the global reach of its product, thus expanding its global profit. This finding implies that the manufacturer should permit gray market trade under some circumstances. Maskus and Chen (2002) construct an economic model in which gray market trade emerges because of the incentive problems in vertical distribution. They show that an original manufacturer does not set a wholesale price that completely prevents gray market trade in equilibrium, by comparing the trade-off between the decrease in demand and limitation of gray market trade by raising its wholesale price. Xiao et al. (2011) show that a manufacturer can benefit from gray market trade by a third-party or authorized dealer, and that both those who benefit and the mechanism by which this benefit occurs depend on the supply chain structure of the manufacturer.

Some studies examine on the impact of gray market trade on the decision making of manufacturers and authorized retailers. Zhang and Feng (2017) theoretically and empirically investigate the pricing of firms facing gray market trade. They show that the price differences between the two independent markets increase the volume of gray market trade, but under certain conditions, it can lead to an increase in firm's profit. Li et al. (2018) investigate gray market trade by both an authorized retailer and third-party parallel importer. They show that the power structure (i.e., the order of decision making) between the retailer and the importer affects the outcomes in each market as well as the profits of each firm. Lu et al. (2020) also investigate the decision making of three firms, a manufacturer, an authorized retailer, and a third-party importer, and show that the third-party importer affects the decision making of both the manufacturer and authorized retailer.

3 Model and assumptions

This section describes our model and the assumptions used in it. Figure 1 illustrates the supply chain structure of our model and Table 1 lists the variables used in our model. As Figure 1 shows, we assume that an MNF manufactures a specific product and sells it in Counties A and B. In addition, we assume that a PI buys a certain amount of the product from Country A's market and resells it in Country B.

Figure 1: Supply chain structure

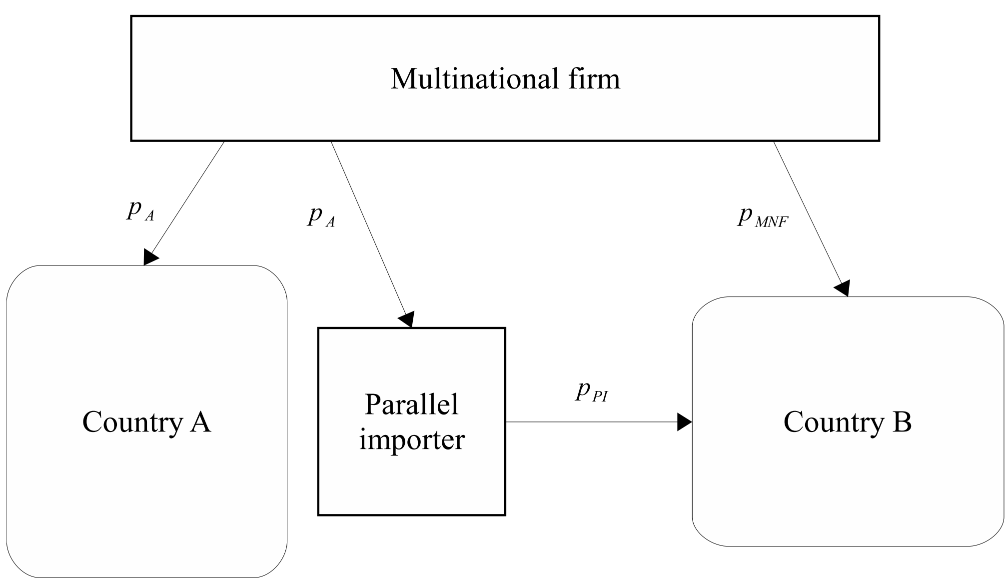


Table 1: Variables List

Notation	
α	Maximum evaluation of a product for consumers in Country A
β	Slope of the inverse demand function in County A
θ	Preference parameter of consumers in Country B
d	Density of consumers inCcountry B
r	Maximum evaluation of a product for consumers in Country B
s	Quality of product in Country B
p_{A}	MNF price in Country A
p_{MNF}	MNF price in Country B
p_{PI}	PI price in Country B
q_{A}	Consumer demand in Country A
q_{MNF}	MNF's selling quantity in Country B
q_{PI}	PI's purchasing quantity in Country A and selling quantity in Country B
Π	MNF's profit
π	PI's profit
$t_{p_{\text{A}}}$	Period in which the MNF chooses the price in Country A
$t_{p_{\text{MNF}}}$	Period in which the MNF chooses the price in Country B
$t_{p_{\text{PI}}}$	Period in which the PI chooses the price in Country B
E	Sequence in which the MNF sets the price in Country B earlier than the PI
S	Sequence in which the MNF and PI set the price in Country B simultaneously
L	Sequence in which the MNF sets the price in Country B later than the PI

In Country A, the MNF sells an authorized product. Suppose that the inverse demand function in Country A is

$$p_{\text{A}} = \alpha - \beta q_{\text{A}}, \tag{1}$$

where p_{A} denotes the price in Country A, q_{A} denotes consumer demand in Country A, and α and β

are positive constants. We may rewrite Equation (1) as the following demand function:

$$q_{\mathrm{A}} = \frac{\alpha - p_{\mathrm{A}}}{\beta}. \tag{2}$$

In Country B, the MNF sells its genuine product through its own authorized channel, and the PI sells the product through its unauthorized channel after purchasing it in Country A's market. We assume vertical product differentiation between the products sold by the MNF and PI. Following Shaked and Sutton (1982), we assume that consumers in Country B have a higher utility from a product with higher quality than a product with lower quality. Moreover, we assume that consumers have different preferences for product quality. To capture the difference in these preferences, we introduce the parameter of $\theta \in \left[\underline{\theta}, \overline{\theta}\right] \subset R_+$ that represents consumer preferences for product quality. We assume that consumers are distributed uniformly along $\left[\underline{\theta}, \overline{\theta}\right]$ with a density of d. To ensure that positive demand arises in equilibrium, we assume that α is sufficiently large to ensure $\alpha > \beta d\left(\overline{\theta} - \underline{\theta}\right)$, and that $\overline{\theta}$ and $\underline{\theta}$ satisfy the inequality $\underline{\theta} < \overline{\theta}/2$. Suppose that the utility functions of consumers in Country B are

$$u_{\mathrm{MNF}} = r - p_{\mathrm{MNF}} + \theta s_{\mathrm{MNF}}, \tag{3}$$

$$u_{\mathrm{PI}} = r - p_{\mathrm{PI}} + \theta s_{\mathrm{PI}}, \tag{4}$$

where r is a sufficiently large positive constant. Henceforth, the subscripts MNF and PI represent the variables for the MNF and PI, respectively. For example, p_{MNF} is the price of the product sold by the MNF, while p_{PI} is the price of the product sold by the PI. Likewise, s_{MNF} and s_{PI} represent the quality of the products sold by the MNF and PI in Country B, respectively. We assume that the quality of the product sold by the PI is lower than that sold by the MNF, so that $s_{\mathrm{MNF}} > s_{\mathrm{PI}} > 0$, and we denote the quality difference between the MNF and PI by $\Delta \equiv s_{\mathrm{MNF}} - s_{\mathrm{PI}}$. Because the consumer is characterized by θ, a consumer indifferent between the authorized and unauthorized products satisfies $r - p_{\mathrm{MNF}} + \hat{\theta} s_{\mathrm{MNF}} = r - p_{\mathrm{PI}} + \hat{\theta} s_{\mathrm{PI}}$. Solving for $\hat{\theta}$ provides

$$\hat{\theta} = \frac{p_{\mathrm{MNF}} - p_{\mathrm{PI}}}{\Delta}. \tag{5}$$

That is, the value of the indifferent consumer preference parameter is established by the ratio of the price and quality differences. Consumers with a high preference parameter value that satisfies $\theta > \hat{\theta}$ buy the product from the MNF, whereas consumers with a low preference parameter value that satisfies $\theta < \hat{\theta}$ buy the product from the PI. The demand functions in Country B are

$$q_{\text{MNF}} = d\left\{\overline{\theta} - \frac{p_{\text{MNF}} - p_{\text{PI}}}{\Delta}\right\}, \tag{6}$$

$$q_{\text{PI}} = d\left\{\frac{p_{\text{MNF}} - p_{\text{PI}}}{\Delta} - \underline{\theta}\right\}. \tag{7}$$

We next state the firms' objective functions. The total profits of the MNF earned in Countries A and B are:

$$\Pi = (p_{\text{A}} - c)(q_{\text{A}} + q_{\text{PI}}) + (p_{\text{MNF}} - c)\,q_{\text{MNF}}, \tag{8}$$

where c is the marginal cost, which is assumed to be normalized to 0. On the contrary, the profit of the PI is

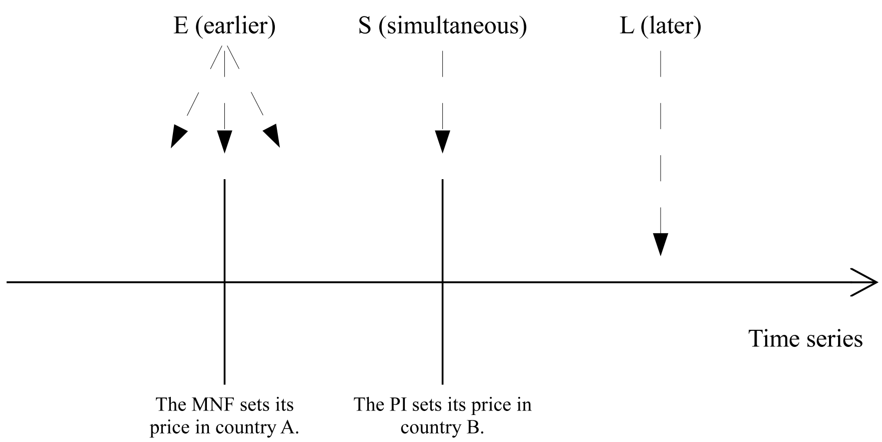
$$\pi = (p_{\text{PI}} - p_{\text{A}})q_{\text{PI}}. \tag{9}$$

Based on these settings, we conceive the observable delay game constructed by Hamilton and Slutsky (1990), which is composed of two stages. In Stage 1, the MNF and PI simultaneously state the period in which they will set their prices and are committed to this statement before they actually do so. In Stage 2, following their statements, the MNF and PI set their prices knowing when to set its price for each other. In the framework of the observable delay game, the sequence of one decision before (after or at the same time as) another is fixed, which allows the analysis to proceed. In other words, the sequence of decisions is an important factor, and in order to consider the sequence of decision making, it is necessary to assume discrete periods. Because there are three control variables, p_{A} , p_{MNF}, and p_{PI}, we suppose that Stage 2 has three periods.

To identify the timing of setting the price, let $t_{p_{\text{A}}}$, $t_{p_{\text{MNF}}}$, and $t_{p_{\text{PI}}}$ represent the timing of the MNF's pricing in Country A, the timing of the MNF's pricing timing in Country B, and the timing of the PI's pricing in Country B, respectively. Since there are three periods in which the MNF and PI set each price, these three variables can be timings of 1, 2, or 3. In other words, in Stage 1 of the game, the MNF determines $t_{p_{\mathrm{A}}}$ and $t_{p_{\mathrm{MNF}}}$ from $\{1,2,3\}$ and the PI determines $t_{p_{\mathrm{PI}}}$ from $\{1,2,3\}$. Because the PI purchases the product in Country A's market and then sells it in Country B, we assume that these timing variables satisfy $t_{p_{\mathrm{A}}} < t_{p_{\mathrm{PI}}}$ such that the PI sets its price after observing the price of the product sold by the MNF in Country A.

4 Analysis

Figure 2: Timeline



Note: The timings E, S, and L shown by the arrows represent when the MNF determines its price in Country B, p_{MNF}.

Substituting Equations (2), (6), and (7) into Equations (8) and (9), we derive the payoffs for the MNF and PI by the timing strategy in Stage 1 of the game. Because Stage 2 has three periods in which each of the three control variables, namely $t_{p_{\mathrm{A}}}$, $t_{p_{\mathrm{MNF}}}$, and $t_{p_{\mathrm{PI}}}$, are set, we need to investigate $3^3 = 27$ sets of the timing sequence to compute all the possible payoffs. However, the constraint $t_{p_{\mathrm{A}}} < t_{p_{\mathrm{PI}}}$ points out that it is sufficient to examine only nine sets of the timing sequence. Moreover, by computing the equilibrium payoffs, we find that while there are nine possible sets of timings, only three case of equilibrium payoffs and variables exist. Accordingly, we separate the equilibrium payoffs and variables using the term "Sequence" for the three prices set. Let Sequences E, S, and L denote that the MNF sets its price in Country B earlier than, simultaneously, and later than, the price of the unauthorized product sold by the PI in Country B, respectively, as Figure 2 illustrates. We define Sequence E as the sequence in which the timing variables are $\left(t_{p_{\mathrm{A}}}, t_{p_{\mathrm{MNF}}}, t_{p_{\mathrm{PI}}}\right) = (1,1,2)$, $(1,1,3)$, $(1,2,3)$, $(2,1,3)$, or $(2,2,3)$ because $t_{p_{\mathrm{MNF}}} < t_{p_{\mathrm{PI}}}$ holds in all these combinations. We define

Sequence S as the sequence in which the timing variables are $\left(t_{p_A}, t_{p_{MNF}}, t_{p_{PI}}\right) = (1,2,2)$, $(1,3,3)$, or $(2,3,3)$ because $t_{p_{MNF}} = t_{p_{PI}}$ holds. Finally, we define Sequence L as the sequence in which the timing variables are $\left(t_{p_A}, t_{p_{MNF}}, t_{p_{PI}}\right) = (1,3,2)$ because $t_{p_{MNF}} > t_{p_{PI}}$ holds. Hereafter, we attach the superscripts E, S, or L to the equilibrium payoffs and variables to identify the sequence of timings. The following proposition shows the equilibrium outcomes by sequence. (The Appendix provides all the proofs.)

Proposition 1. *The equilibrium values of the payoffs and endogenous variables by sequence are as Table 2. The symbol M is defined as $M \equiv \alpha + \beta d\left(\overline{\theta} - \underline{\theta}\right)$.*

Table 2: Equilibrium values

	Sequence E	Sequence S	Sequence L
p_A	$\frac{M}{2}$	$\frac{M}{2}$	$\frac{M}{2}$
p_{MNF}	$\frac{M+\Delta(2\overline{\theta}-\underline{\theta})}{2}$	$\frac{3M+2\Delta(2\overline{\theta}-\underline{\theta})}{6}$	$\frac{2M+\Delta(3\overline{\theta}-2\underline{\theta})}{4}$
p_{PI}	$\frac{2M+\Delta(2\overline{\theta}-3\underline{\theta})}{4}$	$\frac{3M+2\Delta(\overline{\theta}-2\underline{\theta})}{6}$	$\frac{M+\Delta(\overline{\theta}-2\underline{\theta})}{2}$
q_A	$\frac{\alpha-\beta d(\overline{\theta}-\underline{\theta})}{2\beta}$	$\frac{\alpha-\beta d(\overline{\theta}-\underline{\theta})}{2\beta}$	$\frac{\alpha-\beta d(\overline{\theta}-\underline{\theta})}{2\beta}$
q_{MNF}	$\frac{d(2\overline{\theta}-\underline{\theta})}{4}$	$\frac{d(2\overline{\theta}-\underline{\theta})}{3}$	$\frac{d(3\overline{\theta}-2\underline{\theta})}{4}$
q_{PI}	$\frac{d(2\overline{\theta}-3\underline{\theta})}{4}$	$\frac{d(\overline{\theta}-2\underline{\theta})}{3}$	$\frac{d(\overline{\theta}-2\underline{\theta})}{4}$
Π	$\frac{d(2\overline{\theta}-\underline{\theta})\{M+\Delta(2\overline{\theta}-\underline{\theta})\}}{8}+\frac{M(2\alpha-\beta d\underline{\theta})}{8\beta}$	$\frac{d(2\overline{\theta}-\underline{\theta})\{3M+2\Delta(2\overline{\theta}-\underline{\theta})\}}{18}+\frac{M\{3\alpha-\beta d(\overline{\theta}-\underline{\theta})\}}{12\beta}$	$\frac{d(3\overline{\theta}-2\underline{\theta})\{2M+\Delta(3\overline{\theta}-2\underline{\theta})\}}{16}+\frac{M(2\alpha-\beta d\overline{\theta})}{8\beta}$
π	$\frac{d\Delta(2\overline{\theta}-3\underline{\theta})^2}{16}$	$\frac{d\Delta(\overline{\theta}-2\underline{\theta})^2}{9}$	$\frac{d\Delta(\overline{\theta}-2\underline{\theta})^2}{8}$

By comparing the equilibrium variables in Proposition 1, we derive the following two propositions.

Proposition 2. *The equilibrium variables satisfy the following relationships:*

$$p_A^E = p_A^S = p_A^L, \qquad p_{MNF}^E > p_{MNF}^L > p_{MNF}^S, \qquad p_{PI}^E > p_{PI}^L > p_{PI}^S,$$

$$q_A^E = q_A^S = q_A^L, \qquad q_{MNF}^L > q_{MNF}^S > q_{MNF}^E, \qquad q_{PI}^E > q_{PI}^S > q_{PI}^L.$$

Proposition 3. *The equilibrium profits satisfy the following relationships classified depending on the relative degree of the consumer preference parameters $\overline{\theta}$ and $\underline{\theta}$:*

CASE (1) *When* $0 < \underline{\theta} \leq (2-\sqrt{2})\overline{\theta}/2$ *holds:*

$$\pi^E > \pi^L > \pi^S, \qquad \Pi^L \geq \Pi^E \geq \Pi^S.$$

CASE (2) *When* $(2-\sqrt{2})\overline{\theta}/2 < \underline{\theta} < \overline{\theta}/2$ *holds:*

$$\pi^E > \pi^L > \pi^S, \qquad \Pi^E > \Pi^L > \Pi^S.$$

The following corollary is derived from Proposition 2.

Corollary 1. *The equilibrium price difference in Country B is the largest when the MNF sets the price in Country B earlier; that is,*

$$p^E_{MNF} - p^E_{PI} > p^S_{MNF} - p^S_{PI} > p^L_{MNF} - p^L_{PI}.$$

We can identify the optimal timing strategies for the MNF and PI in Stage 1 using the results of Proposition 2. For the compliance of the results, we derive the payoff matrix of the timing game in Stage 1 and propose the Nash equilibrium in the following observation.

Observation 1. *Tables 3 and 4*[3] *illustrate the payoff matrix in Stage 1. The cell in which both payoffs in parentheses are enclosed by a square constitutes the Nash equilibrium in the timing game.*

We use multiplication signs in the cells in Tables 3 and 4 to indicate where the combinations of timing strategies do not satisfy $t_{p_A} < t_{p_{PI}}$. To identify the optimal timing strategy, we enclose the payoff resulting from the optimal strategies of both firms by a square in Tables 3 and 4. Because the left variable in parentheses represents the MNF's payoff and the right variable the PI's payoff, the cell in which the payoffs in parentheses are enclosed by a square constitutes the Nash equilibrium in the timing game, as stated in the observation. We draw the following proposition by referring to Tables 3 and 4.

[3]In Tables 3 and 4, the left variable in parentheses represents the MNF's payoff and the right variable in parentheses represents the PI's payoff from each combination of timing strategies. The payoff enclosed by a square represents the best response for the MNF and PI. Hence, the cell in which both the payoffs in parentheses are enclosed by a square constitutes the Nash equilibrium. The cells with multiplication signs are the unrealized combinations of the strategies because $t_{p_A} < t_{p_{PI}}$ must hold in this timing game. See Proposition 1 for the payoff values, Π^E, Π^S, Π^L, π^E, π^S, and π^L.

Table 3: Payoff matrix in CASE (1)

		Timing strategy by PI: $t_{p_{\mathrm{PI}}}$		
		1	2	3
Timing strategy by MNF: $\left(t_{p_{\mathrm{A}}}, t_{p_{\mathrm{MNF}}}\right)$	$(1,1)$	$\times$	$\left(\Pi^{\mathrm{E}}, \boxed{\pi^{\mathrm{E}}}\right)$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(1,2)$	$\times$	$\left(\Pi^{\mathrm{S}}, \pi^{\mathrm{S}}\right)$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(1,3)$	$\times$	$\left(\boxed{\Pi^{\mathrm{L}}}, \boxed{\pi^{\mathrm{L}}}\right)$	$\left(\Pi^{\mathrm{S}}, \pi^{\mathrm{S}}\right)$
	$(2,1)$	$\times$	$\times$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(2,2)$	$\times$	$\times$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(2,3)$	$\times$	$\times$	$\left(\Pi^{\mathrm{S}}, \boxed{\pi^{\mathrm{S}}}\right)$
	$(3,1)$	$\times$	$\times$	$\times$
	$(3,2)$	$\times$	$\times$	$\times$
	$(3,3)$	$\times$	$\times$	$\times$

Proposition 4. *The combinations of timings that constitute the subgame perfect Nash equilibrium, classified depending on the relative degree of the consumer preference parameters of Country B are summarized as follows:*

CASE (1) *When* $0 < \underline{\theta} \leq (2-\sqrt{2})\overline{\theta}/2$ *holds:*

In this case, the combinations of timings that constitute the subgame perfect Nash equilibrium are $(t_{p_A}, t_{p_{MNF}}, t_{p_{PI}}) = (1,1,3), (1,2,3), (2,1,3), (2,2,3)$, *or* $(1,3,2)$. *The combination of timings* $(1,3,2)$ *corresponds to Sequence L and the other combinations correspond to Sequence E. This suggests that when the lower limit of the consumer preference parameter for product quality is relatively small, an equilibrium arises in which the MNF sets the price in Country B at the last timing.*

CASE (2) *When* $(2-\sqrt{2})\overline{\theta}/2 < \underline{\theta} < \overline{\theta}/2$ *holds:*

In this case, the combinations of timings that constitute the subgame perfect Nash equilibrium are $(t_{p_A}, t_{p_{MNF}}, t_{p_{PI}}) = (1,1,3), (1,2,3), (2,1,3), (2,2,3)$, *or* $(1,1,2)$, *all of which correspond to Sequence E. This suggests that when the lower limit of the consumer preference parameter for product quality is relatively large, the MNF always sets the price in Country B before the PI sets the price in Country B in equilibrium.*

Proposition 2 compares the prices and supply levels in equilibrium of each sequence and points out that the gray market trade volume of Sequence E is more than that of Sequence L, so that

Table 4: Payoff matrix in CASE (2)

		Timing strategy by PI: $t_{p_{\mathrm{PI}}}$		
		1	2	3
Timing strategy by MNF: $\left(t_{p_{\mathrm{A}}}, t_{p_{\mathrm{MNF}}}\right)$	$(1,1)$	$\times$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(1,2)$	$\times$	$\left(\Pi^{\mathrm{S}}, \pi^{\mathrm{S}}\right)$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(1,3)$	$\times$	$\left(\Pi^{\mathrm{L}}, \boxed{\pi^{\mathrm{L}}}\right)$	$\left(\Pi^{\mathrm{S}}, \pi^{\mathrm{S}}\right)$
	$(2,1)$	$\times$	$\times$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(2,2)$	$\times$	$\times$	$\left(\boxed{\Pi^{\mathrm{E}}}, \boxed{\pi^{\mathrm{E}}}\right)$
	$(2,3)$	$\times$	$\times$	$\left(\Pi^{\mathrm{S}}, \boxed{\pi^{\mathrm{S}}}\right)$
	$(3,1)$	$\times$	$\times$	$\times$
	$(3,2)$	$\times$	$\times$	$\times$
	$(3,3)$	$\times$	$\times$	$\times$

$q_{\mathrm{PI}}^{\mathrm{E}} > q_{\mathrm{PI}}^{\mathrm{L}}$. Proposition 3 means that the MNF's profit in equilibrium of each sequence is maximized in Sequence E or L depending on the degree of consumer preference parameters for product quality. Proposition 4 is our central finding and hence provides the managerial implication. It suggests that the optimal timing for the MNF to set its price in Country B varies with the relative degree of the consumer preference parameters for product quality. Specifically, the lower limit of the consumer preference parameter for product quality is smaller than the upper limit, so that $0 < \underline{\theta} \leq (2-\sqrt{2})\overline{\theta}/2$. Hence, it may be optimal for the MNF to set the price in Country B at the last timing. On the contrary, when the lower limit is relatively large, so that $(2-\sqrt{2})\overline{\theta}/2 < \underline{\theta} < \overline{\theta}/2$, the MNF should set the price in Country B before the PI sets its price in Country B.

The results from Propositions 2 and 4 point out that the MNF should prevent gray market trade by the PI give a the large difference of consumer preference parameters for product quality by setting the price in country B at the last timing, and should not prevent such trade by the PI in the gray market otherwise by setting the price before the PI's pricing. In addition, Proposition 3 proposes that the MNF can achieve a higher profit by setting the price in Country B later given a large difference in the consumer preference parameters for product quality. These results imply that the MNF should change the timing of its pricing in the gray market depending on the degree of the consumer preference for product quality.

The intuition behind these outcomes is as follows. We assume that consumers in Country B are uniformly distributed in the interval $[\underline{\theta}, \overline{\theta}]$ at density d. Hence, the relatively small lower limit of the consumer preference parameter so that CASE (1): $0 < \underline{\theta} \leq (2-\sqrt{2})\overline{\theta}/2$ means that the market size of Country B is relatively large in addition to that consumers in Country B have high variation in product quality. By contrast, the relatively large lower limit of the consumer preference parameter so that CASE (2): $(2-\sqrt{2})\overline{\theta}/2 < \underline{\theta} < \overline{\theta}/2$ means that the market size of Country B is relatively large and that consumers have low variation in product quality[4]. Hence, in CASE (1), the market of Country B is relatively attractive for both firms compared with the market of Country A, while in CASE (2), the market of Country A is relatively attractive compared with the market of Country B.

In our model, since the PI resells the products sold by the MNF in the market of Country B, the MNF distributes high-quality products through its own channel and low-quality products through the PI's channel. In other words, choosing the timing of setting the price of Country B by the MNF implies choosing which market is important for the MNF and which channels the MNF offers an advantage in the attractive market. A well-known advantage of price competition is the second-mover advantage indicated by Gal-Or (1985), which means a firm that sets pricing later has a higher profit than a firm that sets pricing earlier. When the difference in the consumer preference parameter for product quality in Country B is relatively small (i.e., when the market of country A is relatively attractive compared with that of country B), the MNF increases the sales volume in Country A by giving the PI the second-mover advantage in Country B. On the contrary, when the difference of consumers preference parameter for product quality in country B is relatively large (i.e., when the market of Country B is relatively attractive compared with that of Country A), the MNF increases the sales volume in Country B by giving its own channel the second-mover advantage.

5 Conclusion

This study investigates the problem of timing in terms of price setting for multinational firms facing gray market trade. The most notable finding from our analysis is that an multinational

[4]Although both the difference in the market size of Country B and the difference in the consumer preference affect the results, our model cannot clearly distinguish these effects.

firm that seeks to maximize its profit should determine its price in the presence of gray market trade depending on the degree of consumer preferences for product quality. Specifically, when the difference in the consumer preference parameter for product quality is relatively small in a market with parallel imports, the multinational firm should set its price before a parallel importer sets its price. On the contrary, when the difference in the consumer preference parameter for product quality is relatively large in a market with parallel imports, the multinational firm should set its price after the parallel importer sets its price. For multinational firms facing the problem of gray market trade, these results offer notable practical implications.

To our knowledge, there is no other study on gray market trade that introduces an observable delay game, except for this study, and we believe that this study is the first step in this field. We conclude by acknowledging limitations of this study and discussing potential avenues for future research. First, we assumed that a multinational firm sells its product directly to both markets. However, some studies (e.g. Zhang and Feng, 2017; Li et al., 2018; Lu et al., 2020) assume that a supplier sells its product through an authorized retailer. To analyze a timing decision involving a supplier, an authorized retailer, and a third-party importer is expected to add an interesting dimension to the problem. Second, we presumed that there is no uncertainty in demand. If there is a high uncertainty of demand in a market with parallel imports, a multinational firm might sell more products in a relatively reliable market without parallel imports and push the risk in the market with parallel imports to a third-party importer. This inference is worth analyzing. Finally, we analyzed the decision making of a multinational firm and parallel importer. However, in general, suppliers (multinational firms) face competition from other suppliers as well as gray market trade by the a third-party importer. The introduction of competition among suppliers is a very interesting issue.

References

Ahmadi, R., Iravani, F., and Mamani, H. (2015). Coping with gray markets: The impact of market conditions and product characteristics. *Production and Operations Management*, 24(5):762–777.

Ahmadi, R., Iravani, F., and Mamani, H. (2017). Supply chain coordination in the presence of gray markets and strategic consumers. *Production and Operations Management*, 26(2):252–272.

Ahmadi, R. and Yang, B. R. (2000). Parallel imports: Challenges from unauthorized distribution channels. *Marketing Science*, 19(3):279–294.

Bucklin, L. P. (1993). Modeling the international gray market for public policy decisions. *International Journal of Research in Marketing*, 10(4):387–405.

Dutta, S., Bergen, M. E., and John, G. (1994). The Governance of Exclusive Territories When Dealers can Bootleg. *Marketing Science*, 13(1):83–99.

EFPIA (2019). The pharmaceutical industry in figures. https://www.efpia.eu/media/413006/the-pharmaceutical-industry-in-figures.pdf.

Gal-Or, E. (1985). Information sharing in oligopoly. *Econometrica*, 53(2):329–343.

Hamilton, J. H. and Slutsky, S. M. (1990). Endogenous timing in duopoly games: Stackelberg or cournot equilibria. *Games and Economic Behavior*, 2(1):29–46.

Iravani, F., Dasu, S., and Ahmadi, R. (2016). Beyond price mechanisms: How much can service help manage the competition from gray markets? *European Journal of Operational Research*, 252(3):789–800.

KPMG (2008). Effective channel management is critical in combating the gray market and increasing technology companies' bottom line. https://agmaglobal.org/uploads/whitePapers/7-10-08KPMGWhitePaperGrayMarketStudy.pdf.

Li, H., Shao, J., and Zhu, S. X. (2018). Parallel importation in a supply chain: The impact of gray market structure. *Transportation Research Part E: Logistics and Transportation Review*, 114:220–241.

Li, Y. (2014). Price leadership in a vertically differentiated market. *Economic Modelling*, 38:67–70.

Lu, Y., Foropon, C. R., Wang, D., and Xu, S. (2020). Arbitrage in gray markets and its impact on supply chain decisions. *Journal of Enterprise Information Management*, 34(1):382–398.

Malueg, D. A. and Schwartz, M. (1994). Parallel imports, demand dispersion, and international price discrimination. *Journal of International Economics*, 37(3-4):167–195.

Maskus, K. E. and Chen, Y. (2002). Parallel imports in a model of vertical distribution: Theory, evidence, and policy. *Pacific Economic Review*, 7(2):319–334.

Maskus, K. E. and Chen, Y. (2004). Vertical price control and parallel imports: Theory and evidence. *Review of International Economics*, 12(4):551–570.

Matsui, K. (2014). Gray-market trade with product information service in global supply chains. *International Journal of Production Economics*, 147(PART B):351–361.

Matsui, K. (2017). When should a manufacturer set its direct price and wholesale price in dual-channel supply chains? *European Journal of Operational Research*, 258(2):501–511.

Richardson, M. (2002). An elementary proposition concerning parallel imports. *Journal of International Economics*, 56(1):233–245.

Shaked, A. and Sutton, J. (1982). Relaxing price competition through product differentiation. *Review of Economic Studies*, 49(1):3–13.

Valletti, T. M. and Szymanski, S. (2006). Parallel trade, international exhaustion and intellectual property rights: A welfare analysis. *Journal of Industrial Economics*, 54(4):499–526.

van Damme, E. and Hurkens, S. (1996). Commitment robust equilibria and endogenous timing. *Games and Economic Behavior*, 15(2):290–311.

van Damme, E. and Hurkens, S. (1999). Endogenous Stackelberg Leadership. *Games and Economic Behavior*, 28(1):105–129.

van Damme, E. and Hurkens, S. (2004). Endogenous price leadership. *Games and Economic Behavior*, 47(2):404–420.

Xiao, Y., Palekar, U., and Liu, Y. (2011). Shades of gray-the impact of gray markets on authorized distribution channels. *Quantitative Marketing and Economics*, 9(2):155–178.

Zhang, Z. and Feng, J. (2017). Price of identical product with gray market sales: An analytical model and empirical analysis. *Information Systems Research*, 28(2):397–412.