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Rules of Origin and Uncertain Compliance Cost

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Abstract

This study considers the role of the cost uncertainty associated with meeting the rules of origin (ROO) in a free trade area/agreement (FTA). While the literature tends to overlook the cost uncertainties of ROO compliers, we show that the uncertain production costs resulting from meeting the ROO yield the coexistence of compliers and non-compliers in symmetric oligopoly firms. We also show that the regime in which compliers and non-compliers coexist is not the best one for an FTA importer, while it may be the best one for world welfare. We also discuss the case that uncertain production costs are firm-specific.

Key words: Rules of origin; Cost uncertainty; Free trade area; Oligopoly

JEL classification: F12; L13; F13; F15

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1 Introduction

In a free trade area/agreement (FTA), firms choose whether to receive duty-free access; to enjoy this access, they must comply with the rules of origin (ROO) established by the FTA.[1] If firms use a certain volume of FTA input to meet the ROO,[2] their products are recognized as "produced within the FTA" and are freely traded inside the area.[3] However, if firms do not meet the ROO, they only pay the destination country's external tariff for exports. Firms have two options: some may comply and others may not. For instance, Anson et al. (2005) find that in the North American Free Trade Agreement (NAFTA), the average FTA utilization (i.e., ROO compliance) rate of Mexican exporters was 64% in 2000. Kohpaiboon (2010) also finds that the utilization rate of Thai exporters in 2008 was lower than 60% when they export to certain countries inside the ASEAN Free Trade Area (AFTA).

Although complying with ROO allows firms to enjoy duty-free access, it can lead to production uncertainties. This is because to meet the ROO, firms must source inputs that originate within the FTA, necessitating a switch of trading suppliers. In short, to meet the ROO, firms must flexibly adjust their production processes by replacing incumbent suppliers outside the FTA with entrant FTA suppliers and making these entrant FTA suppliers their trading partners.[4] This adjustment increases the uncertainty surrounding the ROO complier's production cost.[5] For example, when firms switch trading partners, they face the danger of choosing undesirable suppliers that provide low-quality inputs (Tang and Rai 2014; Wagner and Friedl 2007). Further, when the skills and know-how needed to use the entrant supplier's

[1]In FTAs, the external tariff rates imposed by member countries generally differ. In the absence of regulations, imports from outside the FTA can pass through a member country at the lowest tariff rate, also known as *tariff circumvention*. To prevent tariff circumvention and distinguish between intra-regional trade and outside trade, an FTA needs ROO.

[2]There exist at least three methods of determining the origin of a product: value-added (or physical content) definition, changes in tariff heading, and technical definition. For details, see Falvey and Reed (1998) and WTO (2002).

[3]Many studies consider the negative effects of ROO when purchasing inputs; if regional input prices are higher than the input prices abroad, compliance with the ROO increases production costs. See, for example, Krishna and Krueger (1995), Lopez-de-Silanes, Markusen, and Rutherford (1996), Krueger (1999), Rosellón (2000), Falvey and Reed (2002), Ju and Krishna (2005), and Takauchi (2010, 2011, 2014).

[4]This type of production adjustment is called "partnering flexibility" (Tang and Rai 2014).

[5]Tang and Rai (2014) empirically show that adopting "partnering flexibility" increases performance risk for firms. This empirical evidence is consistent with our setting (i.e., complying with the ROO increases production uncertainty).

input are idiosyncratic, firms incur the costs of learning how to use such inputs effectively (Klemperer 1995; Wagner and Friedl 2007). Thus, firms precisely know the production cost due to FTA sourcing after establishing transactions and producing for a certain period, while they only inaccurately know that cost ex ante.

To examine the cost uncertainty resulting from ROO compliance, we build an oligopoly model based on an FTA comprising two countries: a consuming country and an exporting one housing two firms. The firms choose whether to comply with the ROO. If the firms comply with the ROO, they enjoy a zero tariff rate but suffer uncertain production costs. By contrast, firms who do not comply must pay the external tariff imposed by the consuming country. The timing of the events is as follows. First, the firms decide whether to comply with the ROO. Second, compliers' unit production cost is chosen by using a probability distribution function (PDF) with a positive mean and variance. Lastly, the firms decide their production.

We show that compliers and non-compliers coexist in the equilibrium. If the firms switch their strategy from non-compliance to compliance, they benefit from cost fluctuations but suffer the loss incurred by uncertain costs. The gain and loss depend on the rival's choice: when the rival complies with the ROO, the loss from uncertain costs dominates the gain from cost fluctuations. If the rival does not comply, the gain from cost fluctuations dominates the loss from uncertain costs. Strategic substitutability occurs when the external tariff is at the intermediate level. We also show that the consuming country's welfare tends to decline with an increase in the number of compliers. In our model, the welfare ranking corresponds to the amount of tariff revenue; this is the largest in the non-compliance equilibrium, is half-sized in the coexisting equilibrium of compliers and non-compliers, and disappears in the compliance equilibrium. We find that the degree of the cost uncertainty can have the opposite effect to the consuming country's welfare. If the external tariff is small, a reduction in uncertainty can raise welfare, whereas it decreases welfare if the external tariff is large. If the external tariff is small, both the non-compliance and the coexisting equilibria can appear. A reduction in uncertainty changes the equilibrium from the coexisting one to the non-compliance one and thus welfare rises. On the contrary, only the compliance equilibrium appears if the external tariff is large. A reduction in uncertainty decreases the consumer's benefits from the cost fluctuations of firms, meaning that a reduction in uncertainty decreases welfare. Disclosing relevant information about the FTA suppliers leads to a reduction in the cost fluctuations of ROO-compliant firms. Thus, further information disclosure may harm an FTA-importer.

We further discuss three concerns: world welfare (i.e., the sum of welfare in the consuming and exporting countries), the nature of the coexisting equilibrium in oligopoly, and the case of firm-specific uncertainty. These extensions enable us to obtain further results and policy implications. Considering world welfare reveals that the coexisting equilibrium of compliers and non-compliers can be the best for world welfare among all the regimes. The coexistence of compliers and non-compliers appears in many FTAs, suggesting the status quo may be the best for whole world. The consideration of the coexisting equilibrium in oligopoly shows that if the cost fluctuations are small, the ratio of ROO compliers rises as the number of firms increases. Some empirical studies indicate that the rate of ROO compliers differs among industries and FTAs.[6] The second consideration implies that the rate of ROO compliers alters because of a competitive environment, and this provides a new insight into the context of competition policy within FTAs. The third consideration reveals that firms can comply with the ROO even if the external tariff is sufficiently small. When uncertain production costs are firm-specific and covariance occurs between those costs, the positive effect of cost fluctuations on firms' profit become larger. Then, the incentive to comply with the ROO rises.

This study is related to ROO studies that focus on a firm's choice (Demidova and Krishna 2008; Ishikawa, Mukunoki, and Mizoguchi 2007; Ju and Krishna 2005; Takauchi 2014). Demidova and Krishna (2008) use a monopolistic competition model with firm heterogeneity and show that highly productive firms meet the ROO. Ju and Krishna (2005) and Takauchi (2014) focus on the relationship between the stringency of the ROO and firms' input-purchasing behavior. Ju and Krishna (2005) use a three-country perfect competition model, of which two are FTA members and the other is an outsider, and show that firms comply with the ROO according to the level of internal input price. Takauchi (2014) focuses

[6] Hayakawa et al. (2013) empirically study the reasons underlying the lower FTA utilization rate in AFTA compared with in other FTAs.

on the monopoly power of the input supplier. By using upstream monopoly with a downstream oligopoly model, he demonstrates that the input supplier's monopoly pricing yields the coexistence of compliers and non-compliers in downstream firms. By contrast, Ishikawa, Mukunoki, and Mizoguchi (2007) exclude input markets and introduce price discrimination between compliant and non-compliant goods.[7] They show that the ROO can benefit firms both inside and outside the FTA. Although these works employ various models and consider the coexistence of compliers and non-compliers, they do not examine the role of uncertainty in compliance with the ROO. We thus believe that our model complements existing studies in this regard.

This study is also related to the oligopoly models focusing on demand and cost uncertainties. In a third-country market model, Creane and Miyagiwa (2008) examine whether exporters should disclose information to the government.[8] Although the information structure of their model is similar to ours, they focus on firms' information strategy.

The remainder of the paper is organized as follows. Section 2 presents a duopoly model. Section 3 examines the equilibrium outcomes of the basic model. Section 4 presents the welfare analysis. Section 5 offers three extensions: the first is an analysis of world welfare, the second is a consideration of the coexisting equilibrium under oligopoly, and the third is a consideration of firm-specific production uncertainty, in which the variance differs between two firms and there is covariance between their uncertain production costs. Section 6 concludes. All proofs are depicted in the Appendix.

2 Basic model

We consider an FTA comprising two countries: a consuming country with a final product market and an exporting country without it. Two symmetric exporters in the exporting country supply their products to the consuming country. We call these exporters *firm* i ($i = 1, 2$).

[7] Jinji and Mizoguchi (2016) exclude the input market and focus on the differences in the compliance costs of the ROO between FTA and non-FTA firms.

[8] Creane and Miyagiwa (2009) consider the problem of the choice of technology in the case of uncertainty. They assess whether a monopoly incumbent firm develops new technology when faced with the threat of entry. Creane and Miyagiwa (2010) examine firms' FDI choice under uncertainty.

To focus on the intra-FTA final product market, we exclude exporters located outside the FTA; however, there are competitive input suppliers both inside and outside the FTA. For simplicity, we omit the transport cost.

Firms have two options: one is compliance with the ROO of the FTA and the other is noncompliance. If firms comply with the ROO, they enjoy duty-free access. However, if firms do not comply, they must pay the consuming country's external tariff, t.

To meet the ROO requirements, firms must source a certain volume of inputs inside the FTA. This change in sourcing activity can increase their production uncertainties because by replacing incumbent trading suppliers with entrant regional suppliers and adding these regional suppliers as trading partners, firms must flexibly adjust their trading and production processes to meet the ROO.[9] Suppose that firms have already built a trading relationship with the supplier outside the FTA.[10] Since the outside supplier is a long-term trading partner, firms are knowledgeable about its capabilities (e.g., the quality or characteristics of the provided input).[11] On the one hand, when firms source FTA inputs to meet the ROO, they start trading with regional entrant suppliers. Then, firms might risk choosing an undesirable supplier that provides a low-quality input (Tang and Rai 2014; Wagner and Friedl 2007). Furthermore, the know-how and skills needed to use the input provided by the entrant supplier are often idiosyncratic and hence learning costs for using such inputs effectively may be incurred (Klemperer 1995; Wagner and Friedl 2007).[12] Therefore, ex ante, firms only inaccurately know the cost of sourcing inside the FTA. However, after they establish a trading relation-

[9]This adjustment is closely related to "partnering flexibility" in the context of the buyer–supplier relationship. To improve trading and production processes, firms have two options: one is "process alignment," which is to continue or fix the trading relationship with incumbent suppliers, and the other is "partnering flexibility," which is to flexibly change that relationship (Tang and Rai 2014). Because meeting the ROO brings about a flexible change in the relationship with incumbent suppliers, this implies that partnering flexibility is chosen. However, if firms do not comply with the ROO, the current relationships with incumbent suppliers continue. Hence, the choice of non-compliance with the ROO implies that process alignment is chosen.

[10]When one considers homogeneous inputs, to make the ROO effective, we must assume that the price of the FTA input is higher than that of the non-FTA input. Although we do not explicitly treat input markets, we implicitly assume that the FTA input price is higher than the outside one following existing works of ROO (e.g., Ju and Krishna 2005; Takauchi 2011, 2014).

[11]Tang and Rai (2014) empirically show that the adoption of partnering flexibility raises the performance risk of firms than the adoption of process alignment does. This empirical evidence is consistent with the fact that compliance with the ROO increases production uncertainty.

[12]Tang and Rai (2014) indicate that production uncertainty also arises from a new trading relationship with entrant suppliers because trading experience is lacking.

ship with regional suppliers and engage in a certain period of production activities, the cost of regional sourcing becomes clear. By contrast, if firms do not comply with the ROO, the current relationships with outside suppliers continue. Since production uncertainties do not arise, the unit production cost is thus constant. For simplicity, we normalize the unit production cost of noncompliance with the ROO to 0. However, non-compliers must pay external tariff t, and hence the unit production cost of noncompliance with the ROO is t, which is a positive constant.[13]

Based on these arguments, we consider that the cost of complying with the ROO is uncertain. When firms comply with the ROO, their unit production cost is a random variable. We denote this cost by *compliance cost* c, a random variable with positive mean $\mu = \mathrm{E}c$ and variance $\sigma^2 \equiv \mathrm{Var}(c) = \mathrm{E}c^2 - \mu^2$.[14] We assume that firms are risk neutral and face the same situation when they comply with the ROO.[15] The unit production cost of firm i, c_i, is $c_i = c$ if firm i complies with the ROO and $c_i = t$ if it does not.[16] Although we assume here that unit cost c is common between firms, in Section 5.3 we consider firm-specific uncertainty. In such a case, each firm's unit cost takes a different value even if firms comply with the ROO.

In the consuming country, the inverse demand function of the product is $p = a - bQ$, $a, b > 0$, where p and $Q = q_1 + q_2$ are the price and total sales of the product and q_i is the output of firm i. The profit of firm i is given by $\pi_i \equiv (a - b(q_i + q_j) - c_i)\, q_i$, where $i, j = 1, 2$ and $i \neq j$.

We consider the game to have the following timing of events.[17] Firstly, each firm independently and simultaneously chooses whether to comply (C) or not (N) with the ROO. Secondly, the unit production cost of a complier is chosen from a PDF with positive mean μ and variance σ^2. Finally, each firm competes *à la* Cournot in the consuming country's

[13] To focus on the role of the uncertain ROO compliance cost, we do not consider any tariff on inputs.

[14] For example, consider the following PDF: $f(c) = 1/\beta$ if $0 < c < \beta$; otherwise, $f(c) = 0$.

[15] When two firms are major firms, the assumption of risk neutrality is natural.

[16] Even if uncertainty also occurs from non-compliance with the ROO and the unit production cost in that case is a random variable, our main result does not alter substantially.

[17] A similar timing structure is also employed in Takauchi (2014). Once firms comply with the ROO, they must undertake production arrangement to meet them. This change in the production process results from the change in using inputs. In other words, the decision to comply with the ROO is similar to the technology choice. Because the technology choice involves considerable time and costs, firms find it difficult to frequently change their decisions.

market. This game is solved by using backward induction.

3 Equilibrium outcomes

Second and third stages From the profit of firm i, the first-order condition for profit maximization is

$$a - c_i - 2bq_i - bq_j = 0 \ \ (i, j = 1, 2;\ i \neq j). \tag{1}$$

From (1), we obtain the following:

$$q_1(c_1, c_2) = \frac{a - 2c_1 + c_2}{3b}; \quad q_2(c_1, c_2) = \frac{a + c_1 - 2c_2}{3b}, \tag{2}$$

$$\pi_i(c_1, c_2) = \frac{(a - 2c_i + c_j)^2}{9b}; \quad Q(c_1, c_2) = \frac{2a - c_1 - c_2}{3b}, \tag{3}$$

$$p(c_1, c_2) = \frac{a + c_1 + c_2}{3}; \quad CS(c_1, c_2) = \frac{b[Q(c_1, c_2)]^2}{2}, \tag{4}$$

where $CS(\cdot)$ is the consumer surplus.

We obtain the four cases that depend on the first-stage decisions of firms: NN, CC, CN, and NC. NN denotes the case in which no firm complies with the ROO (*no-complier regime*), CN (NC) denotes the case in which firm 1 (2) complies with the ROO but firm 2 (1) does not (*mixed regime*), and CC denotes the case in which all firms comply with the ROO (*all-compliers regime*). Since all firms are symmetric, CN and NC are the same regime.

From (3), we obtain the following:

$$\pi_i^{NN} = \frac{(a-t)^2}{9b}; \ \pi_i^{CC} = \frac{(a-c)^2}{9b}; \ \pi_1^{NC} = \pi_2^{CN} = \frac{(a+c-2t)^2}{9b}; \ \pi_2^{NC} = \pi_1^{CN} = \frac{(a-2c+t)^2}{9b}. \tag{5}$$

To ensure positive quantities, we set the following restriction on c and t.

Assumption 1. $0 < c < a/2$ *and* $t \leq (a + c)/2$.[18]

Because firms are risk neutral and symmetric, from (5), the expected profit in each regime

[18] In the first stage of the game, Assumption 1 is rewritten as follows: $t, \mu < (a + \min\{t, \mu\})/2 \equiv \gamma$. For all $\sigma^2 \geq 0$, this condition always ensures a positive value for firms' expected profit.

can be written as follows:[19]

$$\mathrm{E}\pi_i^{NN} = \frac{(a-t)^2}{9b}; \quad \mathrm{E}\pi_i^{CC} = \frac{(a-\mu)^2}{9b} + \frac{\sigma^2}{9b}, \tag{6}$$

$$\mathrm{E}\pi_1^{CN} = \frac{(a+t-2\mu)^2}{9b} + \frac{4\sigma^2}{9b} \quad = \mathrm{E}\pi_2^{NC}, \tag{7}$$

$$\mathrm{E}\pi_1^{NC} = \frac{(a-2t+\mu)^2}{9b} + \frac{\sigma^2}{9b} \quad = \mathrm{E}\pi_2^{CN}. \tag{8}$$

The important difference from a Cournot game under certainty is that each firm gains additional rent by complying with the ROO[20] (see the second term[21] in (6)–(8)).

First stage In the first stage, each firm chooses whether to comply with the ROO. To ensure that all three regimes (i.e., no-complier, mixed, and all-compliers) appear in the equilibrium, we need the following assumption.

Assumption 2. *$\sigma^2 < (a-\mu)\mu$.*

For example, a uniform distribution undoubtedly satisfies Assumption 2.

To derive the equilibrium outcomes, let us first consider a firm's best response. From (6)–(8), we obtain Lemma 1.

Lemma 1. *(i) Suppose that the rival (i.e., firm j) chooses N. If $t_L(\sigma^2) \geq t$ ($t_L(\sigma^2) < t$), firm i chooses N (C), where $t_L(\sigma^2) \equiv \mu - \sigma^2/(a-\mu)$. (ii) Suppose that the rival chooses C. If $\mu \geq t$ ($\mu < t$), firm i chooses N (C).*

From Lemma 1, we establish the following result.

[19]In particular, a firm may not behave as an expected profit maximizer. For example, Huck and Weizsäcker (1999) show that their experimental subjects do not always behave in order to maximize expected value. Indeed, in the choice problem of two lotteries, subjects tend to prefer the lottery with fewer possible outcomes and thus the deviation rate from expected value maximization increases. However, even if we introduce such a psychological factor into our model, our result does not qualitatively alter.

[20]To meet the ROO, firms must adjust their production process by changing their inputs. Since this adjustment causes a change in production technology, adjusting the production process to meet the ROO has an aspect of technology choice. Hence, we can consider that meeting the ROO is a kind of investment. In the context of strategic investment, there is a U-shaped relationship between production uncertainty and investment. For example, Henriques and Sadorsky (2011) empirically show a U-shaped relationship between firm-level investment and price volatility in essential inputs such as oil. This finding implies that investment tends to increase as the degree of production uncertainty (i.e., input price volatility) rises above a certain level. In our model, meeting the ROO equates to an increase in production uncertainty. A larger degree of uncertainty (further fluctuations in production costs) raises firms' expected profit and hence greater uncertainty raises the incentive to meet the ROO. This is (partly) consistent with the empirical evidence showing that greater production uncertainty can promote firm-level investment.

[21]This depends on the risk neutrality of firms. See, for example, Creane and Miyagiwa (2008, 2009).

Proposition 1. *(i) If $0 \leq t \leq t_L(\sigma^2)$, the no-complier regime, NN, appears. (ii) If $t_L(\sigma^2) < t < \mu$, the mixed regimes, CN and NC, appear. (iii) If $\mu \leq t < \gamma$, the all-compliers regime, CC, appears. Here, $\gamma \equiv (a + \min\{t, \mu\})/2$.*

Figure 1 illustrates the equilibrium outcomes in the t-σ^2 plane. For any σ^2, an asymmetric outcome occurs. We explain the intuition of Proposition 1 as follows.

[Insert Figure 1 here]

From (3), firm i's profit is convex to its cost c_i. Hence, the expected profit increases with the degree of uncertainty, provided the expected level of unit cost does not change; this is a positive effect of uncertainty. Moreover, if $t \geq \mu$, compliance with ROO does not raise the mean level of unit cost. When $t \geq \mu$, there is no cost of compliance. When all firms choose C, we have an all-compliers regime.

If $t < \mu$, compliance raises the mean level of the unit cost. Hence, there is trade-off between compliance and non-compliance; that is, firms benefit from uncertainty but incur the cost of raising the mean unit cost. Before explaining the intuition in the case where $t < \mu$, we introduce the *mean effect* and *variance effect*. We define the mean effect as the difference between the first terms in (6)–(8). Similarly, the variance effect is the difference between the second terms in (6)–(8). In $\mathrm{E}\pi_i^{NN}$, the second term is zero. If the rival chooses N, the mean effect $\varDelta^N_{Mean}$ and variance effect $\varDelta^N_{Var}$ are

$$\varDelta^N_{Mean} = \frac{(a+t-2\mu)^2}{9b} - \frac{(a-t)^2}{9b}; \;\; \varDelta^N_{Var} = \frac{4\sigma^2}{9b} - 0 = \frac{4\sigma^2}{9b}. \tag{9}$$

If the rival chooses C, the mean effect $\varDelta^C_{Mean}$ and variance effect $\varDelta^C_{Var}$ are

$$\varDelta^C_{Mean} = \frac{(a-\mu)^2}{9b} - \frac{(a-2t+\mu)^2}{9b}; \;\; \varDelta^C_{Var} = \frac{\sigma^2}{9b} - \frac{\sigma^2}{9b} = 0. \tag{10}$$

We consider the effects of switching strategy from N to C. Now, suppose the rival chooses N. From (9), the effects of switching strategy are

$$\frac{(a+t-2\mu)^2}{9b} + \frac{4\sigma^2}{9b} - \frac{(a-t)^2}{9b} = \varDelta^N_{Var} + \varDelta^N_{Mean}.$$

When the rival chooses C, the effects of switching strategy from N to C is (from (10))

$$\frac{(a-\mu)^2}{9b} + \frac{\sigma^2}{9b} - \left[\frac{(a-2t+\mu)^2}{9b} + \frac{\sigma^2}{9b}\right] = \varDelta^C_{Var} + \varDelta^C_{Mean}.$$

Here, since we assume $t < \mu$, compliance raises the mean level of the unit cost. We have

$\varDelta^N_{Mean} < 0$ and $\varDelta^C_{Mean} < 0$. These denote the cost of compliance. On the other hand, the benefit of compliance is $\varDelta^N_{Var} \geq 0$ and $\varDelta^C_{Var} = 0$. Figure 2 illustrates the benefit from and costs incurred when changing from N to C. To illustrate the cost and benefit of compliance in the same plane, we multiply by minus to $\varDelta^N_{Mean}$ and $\varDelta^C_{Mean}$ (In Figure 2, the thick solid (broken) lines denote the case in which the rival's choice is C (N)).

[Insert Figure 2 here]

Figure 2 has the following six properties: (I) $\varDelta^N_{Var}$ and $\varDelta^C_{Var}$ are independent of t, (II) $-\varDelta^N_{Mean}$ and $-\varDelta^C_{Mean}$ decrease with t, (III) when $t = \mu$, $-\varDelta^N_{Mean} = -\varDelta^C_{Mean} = 0$, (IV) when $t = 0$, $\varDelta^N_{Var} + \varDelta^N_{Mean} < 0$, (V) $\varDelta^N_{Var} > \varDelta^C_{Var}$ = 0, and (VI) $-\varDelta^N_{Mean} < -\varDelta^C_{Mean}$. Before explaining why (I)–(VI) hold, we refer to the intuition of Proposition 1. If t is smaller than $t_L(\sigma^2)$, $\varDelta^N_{Mean} > \varDelta^N_{Var}$ and $\varDelta^C_{Mean} > \varDelta^C_{Var}$. That is, regardless of the rival's choice, the cost of changing from N to C exceeds its benefit: NN appears in equilibrium. However, for $t_L(\sigma^2) < t < \mu$, the cost of changing from N to C is larger than its benefit if the rival chooses C; by contrast, the cost is smaller than the benefit if the rival chooses N. CN and NC can appear in equilibrium.

Now, we show why (I)–(VI) hold when $t < \mu$. First, t is not a random variable and thus, has no effect on the variance in an equilibrium outcome. Second, when a firm switches from N to C, the mean level of unit cost increases from t to μ. When t becomes larger, this compliance cost becomes smaller. This is because the difference between t and μ decreases with t. The costs of compliance, $-\varDelta^C_{Mean}$ and $-\varDelta^N_{Mean}$, decrease with t. Third, when $t = \mu$, the mean unit cost does not change, and thus, there is no cost incurred for changing from N to C. Fourth, at $t = 0$, the cost of changing from N to C is the highest. Hence, the cost of compliance exceeds its benefit.

Fifth, the size of the variance effect depends on the difference between the variance of profit with N and that with C. When the rival chooses N, there is no variance effect if the firm also chooses N. This is because the profit does not include the random variable c. In contrast, when the firm chooses C, the profit has c. The variance effect of changing from N to C is positive if the rival chooses N. That is, we have $\varDelta^N_{Var} > 0$. Next, we consider the case where the rival complies with ROO. Regardless of one's choice, there is a random variable c in the profit. From (5), the firm's profit is $(a+c-2t)^2/9b$ when it does not comply with ROO and $(a-c)^2/9b$ when it does. The variance effect depends on the absolute value of the coefficient of random variable in the profit functions. Because the absolute values are the same, the variance effect does not change even if the firm switches from N to C. We have $\Delta^C_{Var} = 0$ and (V) holds.

Finally, the mean effect depends on a decrease in the mean term in the expected profit when the firm switches strategy from N to C. Even if the changes in the unit cost of the firm are the same, the mean effects differ by unit cost for the rival. If the rival chooses C, the unit cost of the rival is significantly high. Thus, the firm has a larger profit because the market is not competitive. The firm loses large profits when it switches from N to C and its unit cost increases. However, if the rival chooses N, the market becomes competitive because its unit cost is small. Then, the firm earns a small profit. Hence, even if the firm switches from N to C, the loss is small. Therefore, the mean effect of the rival's compliance is larger than that of the rival's non-compliance. We have $-\Delta^C_{Mean} > -\Delta^N_{Mean}$.

4 Welfare analysis

Here, we examine the effects of external tariff t and the variance in compliance cost σ^2 on the consuming country's welfare.

Consumer surplus in the consuming country From (4), the expected consumer surplus in each regime is

$$\mathrm{E}CS^{NN} = \frac{2(a-t)^2}{9b}, \tag{11}$$

$$\mathrm{E}CS^{CC} = \frac{2(a-\mu)^2}{9b} + \frac{2\sigma^2}{9b}, \tag{12}$$

$$\mathrm{E}CS^{NC} = \frac{(2a-t-\mu)^2}{18b} + \frac{\sigma^2}{18b} = \mathrm{E}CS^{CN}. \tag{13}$$

We first consider the relationship between the expected consumer surplus and t. From (11)–(13), we have the following result.

Proposition 2. *(i) In the no-complier and mixed regimes, the expected consumer surplus decreases for the external tariff, whereas it is constant for the external tariff in the all-compliers regime. (ii) The expected consumer surplus in the no-complier regime is larger than that in the mixed regime at $t = t_L(\sigma^2)$; however, at $t = \mu$, the expected consumer surplus in the no-complier regime is smaller than that in the mixed regime.*

[Insert Figure 3 here]

Proposition 2 can be interpreted as follows. First, in the no-complier and mixed regimes, the expected consumer surplus decreases with the external tariff rate t. In the all-compliers regime, the expected consumer surplus is constant. Second, when a sufficiently small increase in t changes from the no-complier to the mixed regime, this change reduces the expected consumer surplus. On the contrary, when a sufficiently small increase in t changes from the mixed to the all-compliers regime, this change raises the expected consumer surplus (see Figure 3).

We consider the intuition in part (i) of Proposition 2. First, for $t \geq \mu$, all firms choose compliance and any change in t has no effect on firms' costs. This means that firms' outputs also do not change. $\mathrm{E}CS^{CC}$ is constant. Second, for $t \in [0, \mu)$, at least one firm pays an external tariff. Thus, an increase in t raises firms' costs. Therefore, an increase in t reduces aggregate output and the expected consumer surplus.

The intuition in part (ii) of Proposition 2 is as follows. From (13), we have

$$\mathrm{E}CS^{NC} = \mathrm{E}CS^{CN} = \frac{2[a - (t + \mu)/2]^2}{9b} + \frac{\sigma^2}{18b}.$$

We find that the difference in the first terms of (11)–(13) is the average unit cost in each regime. That is, the average unit cost is t (μ and $(t + \mu)/2$) in the no-complier regime (all-compliers and mixed regimes). If $t < \mu$, an increase in the number of compliers raises the average unit cost. Hence, the higher the number of compliers, the smaller is aggregate output. On the contrary, an increase in the number of compliers results in a larger variance effect (see (11)–(13)). Since the variance effect is positive, a change in regime has the opposite effect on the expected consumer surplus. In our model, the negative effect dominates the positive one at $t = t_L(\sigma^2)$. Hence, a change from the no-complier to the mixed regime decreases the expected consumer surplus. On the contrary, if $t = \mu$, the average unit cost is the same for all regimes. Since the negative effect vanishes, a change from the mixed to the all-compliers regime raises the expected consumer surplus.

From the consumer's view, we have the following policy implication. Suppose that the external tariff t is high and the all-compliers regime appears. Then, a small reduction in t may harm consumers because the expected consumer surplus suddenly drops at $t = \mu$. Hence, to enhance the consumer's benefit, the government of the consuming country must decrease t markedly and achieve a no-complier regime (see Figure 3).

We next consider the effects of reducing variance. A reduction in σ^2 may enhance the consumer's benefit if t is low enough. To see this, we present Figures 4 and 5. When $\mu > t$, the no-complier and mixed regimes appear corresponding to the size of σ^2. On the contrary, when $\mu \leq t$, only the all-compliers regime appears (see Proposition 1 and Figure 1).

[Insert Figures 4 and 5 here]

There are two cases when $\mu > t$: one is a sufficiently low tariff (i.e., $t \leq \tilde{t} < \mu$),[22] in which a reduction in σ^2 can raise the consumer surplus (see panel (a) of Figure 4). Because t is sufficiently low, the expected consumer surplus in the no-complier regime is larger than that in the mixed regime. The other is the case that $\mu > t > \tilde{t}$. In such a case, a reduction in σ^2 may reduce the consumer surplus (see panel (b) of Figure 4). Although the expected consumer surpluses in the no-complier and mixed regimes decrease with t, those rankings reverse when t rises above a certain level within the range $\mu > t$ (see the proof of Proposition 2). Hence, if t is close to μ, the expected consumer surplus in the mixed regime can be larger than that in the no-complier regime. By contrast, only the all-compliers regime appears when $\mu \leq t$, and thus a reduction in σ^2 harms consumers in that case (see Figure 5).

When the origin country of the inputs examines its local suppliers in detail and actively discloses the obtained knowledge, the size of σ^2 may decrease. Therefore, if t is low enough, the information disclosure can increase the consumer's benefit.

Social surplus in the consuming country The expected social surplus of the consuming country, $\mathrm{E}W$, comprises the expected consumer surplus, $\mathrm{E}CS$, and the expected tariff

[22] The detailed calculations are depicted in the Appendix (Figure 4).

revenue, $\mathrm{E}TR$. By using (2) and (11)–(13), we obtain the following:

$$\mathrm{E}W^{NN} \equiv \mathrm{E}CS^{NN} + \mathrm{E}TR^{NN} = \frac{2}{9b}(a-t)(a+2t), \tag{14}$$

$$\mathrm{E}W^{NC} \equiv \mathrm{E}CS^{NC} + \mathrm{E}TR^{NC} = \frac{1}{18b}(2a-t-\mu)^2 + \frac{1}{3b}(a-2t+\mu)t + \frac{\sigma^2}{18b}, \tag{15}$$

$$\mathrm{E}W^{CC} \equiv \mathrm{E}CS^{CC}. \tag{16}$$

By comparing (14)–(16), we have the following result.

Proposition 3. *For a given rate of the external tariff, the consuming country's welfare ranking is* $\mathrm{E}W^{NN} > \mathrm{E}W^{NC} = \mathrm{E}W^{CN} > \mathrm{E}W^{CC}$ *if* $0 < t < t^+$*, and* $\mathrm{E}W^{NN} > \mathrm{E}W^{CC} \geq \mathrm{E}W^{NC} = \mathrm{E}W^{CN}$ *if* $t^+ \leq t < \gamma$*. Here,* $t^+ \equiv \left(a + 4\mu + \sqrt{a^2+52a\mu-17\mu^2-33\sigma^2}\right)/11$.

Proposition 3 shows that welfare in the no-complier regime is the best among all the other regimes for the following reasons. In a no-complier regime, there are no compliers and hence the variance term does not emerge (see (14)). However, in this regime, two firms pay an external tariff and the consuming country gains the largest tariff revenue among all the regimes. This tariff revenue lifts the regime's welfare upward considerably, and the welfare of the no-complier regime becomes the largest among all the other regimes. Furthermore, because tariff revenue tends to increase with the rate of the external tariff, the welfare of this regime also tends to increase with the external tariff.

A mixed regime includes a non-complier. Thus, in this regime, the consuming country gains tariff revenue that is at least half that in the no-complier regime. Further, the variance term is no more than half that in the all-compliers regime (see (15)). However, the upward effects of tariff revenue and the variance terms are not very large and the expected consumer surplus decreases with the external tariff t. Thus, welfare in the mixed regime decreases with t when its rate exceeds a critical level. By contrast, since there are no non-compliers and no tariff revenue emerges in the all-compliers regime, welfare remains constant. Thus, the welfare ranking between the mixed and all-compliers regimes can reverse if t is high.

[Insert Figure 6 here]

As shown in Proposition 3, we find that if the initial rate of t is sufficiently high, the consuming country can improve domestic welfare to reduce t. In particular, it is desirable for that country to reduce t to achieve a no-complier regime (see Figure 6).

On the one hand, in contrast to the effects of t, we should be careful about the extent to which variance affects the welfare of the consuming country because the welfare effects of reducing σ^2 can be reversed between the two cases of a low external tariff and a high external tariff (see Figure 7).

[Insert Figure 7 here]

In the case of a low external tariff (panel (a) of Figure 7), a reduction in σ^2 can improve the consuming country's welfare. Hence, the promotion of information disclosure can raise the welfare of the consuming country. On the contrary, in the case of a high external tariff (panel (b) of Figure 7), a reduction in σ^2 reduces welfare. Then, it is undesirable for the consuming country to promote information disclosure.

5 Extensions

We present three extensions to the model. The first extends the relationship between world welfare and the external tariff, the second relates to an oligopoly, and the third concerns the case that the variance in the compliance cost is firm-specific.

5.1 World welfare

We consider the relationship between world welfare and t. In contrast to the argument concerning the consuming country's welfare, the mixed regime can maximize world welfare. In this part, we focus on this issue.[23]

World welfare is given by the sum of the consuming country's social surplus and firms' profits. Thus, we have

$$
\begin{aligned}
\mathrm{E}WW^{NN} &\equiv \mathrm{E}W^{NN} + \mathrm{E}\pi_1^{NN} + \mathrm{E}\pi_2^{NN} = \frac{2(a-t)(2a+t)}{9b},\\
\mathrm{E}WW^{NC} &\equiv \mathrm{E}W^{NC} + \mathrm{E}\pi_1^{NC} + \mathrm{E}\pi_2^{NC} = \frac{8a(a-\mu) + 11\mu^2 + 11\sigma^2 - 2(a+4\mu)t - t^2}{18b},\\
\mathrm{E}WW^{CC} &\equiv \mathrm{E}W^{CC} + \mathrm{E}\pi_1^{CC} + \mathrm{E}\pi_2^{CC} = \frac{4(a-\mu)^2 + 4\sigma^2}{9b},
\end{aligned}
$$

[23] Although it is analytically impossible to completely illustrate the ranking of world welfare, we can show a sufficient condition for which the mixed regime maximizes world welfare.

where $\mathrm{E}\pi_2^{NC} = \mathrm{E}\pi_1^{CN}$.

From these, we establish the following.

Proposition 4. *Suppose that $\mu < a/9$ and $\sigma^2 \geq 2(5a - \mu)\mu/11$. Then, the mixed regime always maximizes world welfare.*

[Insert Figure 8 here]

Figure 8 shows Proposition 4. A higher external tariff makes production more inefficient and its effect is dominant, and thus world welfare in the no-complier and mixed regimes decreases as the external tariff rises. Furthermore, in the range $\mu > t$, because world welfare in the all-compliers regime is the worst among all the other regimes, a reduction in t may improve world welfare.[24] However, the no-complier regime does not always maximize world welfare. Proposition 4 provides a sufficient condition for which the mixed regime is the best among all the regimes. The reason is explained by the variance term in a firm's expected profit. In the mixed regime, ROO compliers and non-compliers coexist. By complying with the ROO when the rival does not comply, the complier gains the largest variance term among all the regimes (see (7)). At the same time, non-compliers also gain from the variance term owing to the uncertainty in the rival's cost. Hence, the sum of a firm's variance term is the largest among all the regimes. When the mean μ is small, because μ represents the cost of complying with the ROO, the cost incurred by compliers is small. Because the mean μ and variance σ^2 do not appear in the no-complier regime, world welfare in the mixed regime is larger than that in the no-complier regime when μ is small and the variance σ^2 is large. Although the variance term also appears in the all-compliers regime, its size is small (see (6)). Therefore, when the external tariff is sufficiently high and world welfare in the no-complier and mixed regimes is sufficiently small (i.e., in the range $\mu < t$), world welfare in the all-compliers regime can be larger than that in the other regimes.

Since ROO compliers and non-compliers coexist in many FTAs, we can consider that the mixed regime appears in the real world. Proposition 4 implies that in view of world welfare, the status quo can be the most efficient regime. Therefore, a reduction in the external tariff from the status quo level may worsen world welfare.

[24] See the proof of Proposition 4.

5.2 Mixed regime under many firms

Here, we assume that m ($\leq n$) firms comply with the ROO, implying that $n - m$ firms do not, where n (≥ 2) is the number of firms. The profit of firm $i \in \{1, \dots, n\}$ is $\pi_i = \big(a - b\sum_{j=1}^{n} q_j - c_i\big)q_i$. The first-order condition of profit maximization leads to

$$\pi_i = \frac{[a - (1+n)c_i + mc + (n-m)t]^2}{b(1+n)^2},$$

where $c_i = c$ if firm i complies with the ROO and $c_i = t$ otherwise.

The expected profit in the first stage of the game is

$$\mathrm{E}\pi_i^C = \frac{[a - (1+n-m)\mu + (n-m)t]^2}{b(1+n)^2} + \frac{(1+n-m)^2\sigma^2}{b(1+n)^2}, \tag{17}$$

$$\mathrm{E}\pi_i^N = \frac{[a + m\mu - (1+m)t]^2}{b(1+n)^2} + \frac{m^2\sigma^2}{b(1+n)^2}, \tag{18}$$

where C (N) denotes the equilibrium outcome in which the firm complies (does not comply) with the ROO. Since $\mathrm{E}\pi_i^C = \mathrm{E}\pi_i^N$ must be satisfied in the equilibrium, solving it for m leads to the equilibrium number of ROO-compliant firms, m^*:[25]

$$m^* = \frac{1+n}{2} + \frac{(a-t)(t-\mu)}{(t-\mu)^2 + \sigma^2}.$$

We consider the effect of an increase in n on the ratio of compliers m^*/n. By differentiating m^*/n with respect to n, we obtain $\partial(m^*/n)/\partial n = [(\mu-t)(2a-t-\mu)-\sigma^2]/(2n^2[\sigma^2+(t-\mu)^2])$. From these results, we obtain the following.

Proposition 5. *Suppose there are n (≥ 2) firms. (i) The number of ROO compliers in the mixed regime equilibrium is $m^* = (1+n)/2 + (a-t)(t-\mu)/[(t-\mu)^2 + \sigma^2]$. (ii) An increase in the number of firms increases the ratio of ROO compliers, m^*/n, if and only if $\sigma^2 < (\mu - t)(2a - t - \mu)$ and $\mu > t$.*

Even when the variance is small, why does keener competition among firms raise the

[25] To ensure $0 \leq m^* \leq n$, we need the following restrictions. (i) If $t < \mu$, we assume that $(n+1)/2 \geq (a-t)(\mu-t)/[(t-\mu)^2+\sigma^2]$ and (ii) if $t > \mu$, we assume that $(n-1)/2 \geq (a-t)(t-\mu)/[(t-\mu)^2+\sigma^2]$.

ratio of ROO compliers? We explain this by using (17) and (18). The derivation yields

$$\frac{\partial \mathrm{E}\pi_i^C}{\partial n} = -\frac{2[a-(1+m)t+m\mu][a-(n-m)t-(1+n-m)\mu]}{b(1+n)^3} + \underbrace{\frac{2(1+n-m)m\sigma^2}{b(1+n)^3}}_{>0},$$

$$\frac{\partial \mathrm{E}\pi_i^N}{\partial n} = -\frac{2[a-(1+m)t+m\mu]^2}{b(1+n)^3} - \frac{2m^2\sigma^2}{b(1+n)^3} < 0.$$

For now, let us assume that the number of compliers, m, does not change. If n increases, a non-complier's profit would decrease because an increase in n implies an increase in the number of non-compliers. Thus, non-compliers have an incentive to comply. To maintain a mixed regime, the profit of compliers should not increase. From (17) and (18), the first term of compliers' profit is ambiguous with regard to an increase in n. By contrast, the second term increases with n because an increase in the number of firms implies an increase in that of non-compliers and the rent resulting from the variance expands. In this case, compliers' profit may decrease when m increases. Because the number of firms receiving rent from the variance increases, the per-capita rent of compliers reduces. However, the effect of an increase in the second term dominates any other effect when the variance is large; thus, the profit of compliers may increase with n. Therefore, to increase the number of compliers to maintain the mixed regime for an increase in n, the variance must be small.

5.3 Firm-specific uncertainty

We consider the case with firm-specific uncertainty here. We assume that c_i is the compliance cost of firm i and it has a positive mean μ and variance σ_i^2. We denote the covariance of these random variables by Cov.

From (2) and (3), we have the following expected profits in each regime:[26]

$$\mathrm{E}\bar{\pi}_i^{NN} = \frac{(a-t)^2}{9b}; \;\; \mathrm{E}\bar{\pi}_i^{CC} = \frac{(a-\mu)^2}{9b} + \frac{4\sigma_i^2+\sigma_j^2-4Cov}{9b} \;\; (i \neq j), \tag{19}$$

$$\mathrm{E}\bar{\pi}_1^{CN} = \frac{(a+t-2\mu)^2}{9b} + \frac{4\sigma_1^2}{9b}; \;\; \mathrm{E}\bar{\pi}_2^{CN} = \frac{(a-2t+\mu)^2}{9b} + \frac{\sigma_1^2}{9b}, \tag{20}$$

$$\mathrm{E}\bar{\pi}_1^{NC} = \frac{(a-2t+\mu)^2}{9b} + \frac{\sigma_2^2}{9b}; \;\; \mathrm{E}\bar{\pi}_2^{NC} = \frac{(a+t-2\mu)^2}{9b} + \frac{4\sigma_2^2}{9b}. \tag{21}$$

[26]We denote the firm's profit as "$\bar{\pi}_i$" to distinguish it from that in the previous section.

Note that in the case where the firms face the same random variable, $\sigma_i^2 = Cov$ holds. By comparing the expected profits in Section 3, we find the effects of the covariance. When the unit costs in the all-compliers regime positively correlate, $\mathrm{E}\bar{\pi}_i^{CC}$ has a small value because a positive correlation leads to similar technologies for firms. Then, each firm earns neither large nor small profits. Hence, a positive correlation mitigates the variance effect on profits.

Here, we discuss an incentive to comply with the ROO. First, we consider a case where a rival firm does not comply. Since at least one firm does not comply, we do not need to consider the effects of the covariance. Hence, the condition for complying is similar to that in Section 3. In particular, $\mathrm{E}\bar{\pi}_1^{NN} - \mathrm{E}\bar{\pi}_1^{CN} \geq 0$ and $\mathrm{E}\bar{\pi}_2^{NN} - \mathrm{E}\bar{\pi}_2^{NC} \geq 0$ lead to $t \leq \mu - \sigma_i^2/(a-\mu) \equiv T_L(\sigma_i^2)$. Next, we consider a case where a rival firm complies. From $\mathrm{E}\bar{\pi}_1^{NC} - \mathrm{E}\bar{\pi}_1^{CC} \geq 0$ and $\mathrm{E}\bar{\pi}_2^{CN} - \mathrm{E}\bar{\pi}_2^{CC} \geq 0$, we have $Cov - \sigma_i^2 \geq (a-t)(t-\mu)$.

When the unit costs in the all-compliers regime are positively correlated, the profit of each firm is distributed over a narrow range because firms share similar technologies. Hence, the variance effect on profits weakens and each firm tends to choose non-compliance. On the contrary, if the unit costs are independent or negatively correlated, firms face large variance effects. Hence, even if external tariff t is smaller than the mean unit cost with compliance μ, the firms may choose to comply with the ROO.

Proposition 6. *Suppose that the covariance between unit costs with compliance is small and the variances in unit costs with compliance are large. Then, firms can comply with the ROO even if the external tariff is smaller than the mean of the unit costs.*

[Insert Figure 9 here]

In Figure 9, two solid lines divide the figure into three regions. In the left region, the decision to comply with the ROO does not depend on the rival's choice and no firm complies with the ROO. In the right region, firms always comply with the ROO. In the central region, one firm complies with the ROO if and only if the other does not.

Here, suppose a case with $(\sigma_1^2, \sigma_2^2, t) = (\sigma'^2_1, \sigma'^2_2, t')$ denoted by the points A and B in Figure 9. Then, both firms comply with the ROO even if the expected unit cost μ is larger than external tariff t'. Hence, when the cost uncertainty is firm-specific, the covariance becomes important and a small covariance yields both firms' compliance under $t < \mu$.[27]

6 Conclusion

This study focuses on the uncertain production costs resulting from compliance with the ROO and examines the effects of this uncertainty on the choice of firms in a simple oligopoly model based on an FTA. We show that an uncertain compliance cost and strategic substitutability among firms' choices are important for the coexistence of compliers and non-compliers. If the rate of the external tariff is sufficiently low, non-compliance becomes the dominant strategy and the no-complier regime emerges. By contrast, if the rate of the external tariff is sufficiently high, the benefit from the cost uncertainty becomes relatively large and the all-compliers regime appears. For an intermediate external tariff, strategic substitutability among firms' choices emerges and the mixed regime appears.

We also show that the welfare of the consuming country tends to decrease with an increase in the number of compliers. The best is the no-complier regime, followed by the mixed regime, and the worst being the all-compliers regime. This is because the degree of uncertainty is not very large and tariff revenue places a larger weight on welfare. We further examine the effects of the degree of uncertainty on the consuming country's welfare and show that a reduction in the cost uncertainty may have the entirely opposite effects on welfare. If the external tariff is small, a reduction in uncertainty can raise welfare. Because a reduction in uncertainty can change the regime from the mixed regime to the no-complier regime, welfare can rise. However, if the external tariff is large, because only the all-compliers regime appears, a reduction in uncertainty always decreases welfare.

In contrast to the welfare of the consuming country, in view of world welfare, the mixed regime can be the best among all the other regimes. Because the variance term of firms' expected profit is the largest in the mixed regime, this can make world welfare the largest. We further discuss the case of firm-specific uncertainty. If the variance in production costs is firm-specific and there is covariance between production costs, the all-compliers regime can appear even though the external tariff is sufficiently small. In such a case, each firm faces

[27]This important issue was pointed out by an anonymous referee. We thank him/her for this comment.

a larger variance effect, meaning that firms can comply with the ROO when the external tariff is smaller than the mean unit cost of ROO compliance. We also extend duopoly to oligopoly and derive the ratio of compliers in a mixed regime. We demonstrate that if the variance is small, the ratio of compliers increases with the number of firms. This result has much significance. In fact, the ratio of ROO compliers generally differs among industries and FTAs. Therefore, we need to consider the factors that yield this difference and affect the ratio of ROO compliers. Since our result implies that a competitive environment within an FTA changes the ratio of ROO compliers, we believe that our model offers a new insight into the context of competition policy inside FTAs.

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Appendix: Proofs

Proof of Lemma 1. First, $\mathrm{E}\pi_1^{NN} - \mathrm{E}\pi_1^{CN} = 4(a-\mu)[t_L(\sigma^2)-t]/9b = \mathrm{E}\pi_2^{NN} - \mathrm{E}\pi_2^{NC}$, where $t_L(\sigma^2) \equiv \mu - \sigma^2/(a-\mu)$. $0 < t_L(\sigma^2) < \mu$, provided $0 < \sigma^2 < (a-\mu)\mu$. Thus, we obtain the following: $\mathrm{E}\pi_1^{NN} \geq (<) \ \mathrm{E}\pi_1^{CN}$ if $t_L(\sigma^2) \geq (<) \ t$; $\mathrm{E}\pi_2^{NN} \geq (<) \ \mathrm{E}\pi_2^{NC}$ if $t_L(\sigma^2) \geq (<) \ t$. Further, $\mathrm{E}\pi_1^{NN} - \mathrm{E}\pi_1^{CN}$ $(= \mathrm{E}\pi_2^{NN} - \mathrm{E}\pi_2^{NC}) \leq 0$ if $t \geq \mu$. Second, $\mathrm{E}\pi_1^{NC} - \mathrm{E}\pi_1^{CC} = [4(a-t)(\mu-t)]/9b = \mathrm{E}\pi_2^{CN} - \mathrm{E}\pi_2^{CC}$. From this, $\mathrm{E}\pi_1^{NC} > (\leq) \ \mathrm{E}\pi_1^{CC}$, and $\mathrm{E}\pi_2^{CN} > (\leq) \ \mathrm{E}\pi_2^{CC}$ if $t < (\geq) \ \mu$. Q.E.D.

Proof of Proposition 2. (i) Differentiating the expected consumer surplus for t leads to $\partial \mathrm{E}CS^{NN}/\partial t = -4(a-t)/9b < 0$, $\partial \mathrm{E}CS^{CN}/\partial t = \partial \mathrm{E}CS^{NC}/\partial t = -(2a-t-\mu)/9b < 0$, and $\partial \mathrm{E}CS^{CC}/\partial t = 0$. (ii) $\mathrm{E}CS^{NN} - \mathrm{E}CS^{NC} = -[\sigma^2 + (4a-3t-\mu)(t-\mu)]/18b$. Note that $\mathrm{E}CS^{NC} = \mathrm{E}CS^{CN}$. At $t = 0$, $\mathrm{E}CS^{NN} - \mathrm{E}CS^{NC} = [(4a-\mu)\mu - \sigma^2]/18b > 0$. At $t = t_L(\sigma^2)$, $\mathrm{E}CS^{NN} - \mathrm{E}CS^{NC} = \sigma^2[(a-\mu)^2 + \sigma^2]/6b(a-\mu)^2 > 0$. At $t = \mu$, $\mathrm{E}CS^{NN} - \mathrm{E}CS^{NC} = -\sigma^2/18b < 0$ and $\mathrm{E}CS^{NC} - \mathrm{E}CS^{CC} = -\sigma^2/6b < 0$. Q.E.D.

Proof of Proposition 3. First, $\mathrm{E}W^{NN} - \mathrm{E}W^{NC} = [3t^2 + 2(a-4\mu)t + (4a-\mu)\mu]/18b - \sigma^2/18b$. $\mathrm{E}W^{NN} > \mathrm{E}W^{NC}$ is equivalent to $\sigma^2 < 3t^2 + 2(a-4\mu)t + (4a-\mu)\mu \equiv \delta$. We prove that $\mathrm{E}W^{NN} > \mathrm{E}W^{NC}$. Above all, we verify $\delta > 0$. When $\mu \leq a/4$, $\delta > 0$. Suppose $\mu > a/4$.

The discriminant of $\delta = 0$ is $4(a-19\mu)(a-\mu)$ and this has a negative value. Since δ is U-shaped for t, $\delta > 0$ holds. From the upper limit of σ^2, $(a-\mu)\mu - \delta = -3t^2 - 3a\mu - 2(a-4\mu)t$. For $\mu \leq a/4$, $\delta > (a-\mu)\mu$, and thus $\mathrm{E}W^{NN} > \mathrm{E}W^{NC}$. Next, we consider the case of $\mu > a/4$. The discriminant of the equation $(a-\mu)\mu - \delta = 0$ is $(a-16\mu)(a-\mu)$. Since $\mu > a/4$, the discriminant $(a-16\mu)(a-\mu)$ has a negative value. $(a-\mu)\mu - \delta$ is inverted U-shaped for t and does not have a real root: $\delta > (a-\mu)\mu$. Thus, $\mathrm{E}W^{NN} > \mathrm{E}W^{NC}$.

Second, $\mathrm{E}W^{NN} - \mathrm{E}W^{CC} = 2[(a-2t)t + (2a-\mu)\mu - \sigma^2]/9b$. $\mathrm{E}W^{NN} > \mathrm{E}W^{CC}$ is equivalent to $\sigma^2 < (a-2t)t + (2a-\mu)\mu \equiv \lambda$. We verify $\lambda > 0$. By solving $\lambda \geq 0$ for t, we have $0 < t < \bar{t} \equiv [a + \sqrt{a^2 + 16a\mu - 8\mu^2}]$. Since $\gamma > \mu$, we obtain $\lambda|_{t=\gamma=(a+\mu)/2} = 3(a-\mu)\mu/2 > 0$ at the point of $t = \gamma$. This implies that $\bar{t} > \gamma$ and $\lambda > 0$ for all t. We prove that $\mathrm{E}W^{NN} > \mathrm{E}W^{CC}$. For a given $\mu > 0$, $(a-2t)t + (2a-\mu)\mu$ is inverted U-shaped for t. Thus, if t has the smallest or largest value and $(a-2t)t + (2a-\mu)\mu > \sigma^2$ holds, $\mathrm{E}W^{NN} > \mathrm{E}W^{CC}$. At $t = 0$, $(a-2t)t + (2a-\mu)\mu = (2a-\mu)\mu$ and $(2a-\mu)\mu > (a-\mu)\mu$. When $t > \mu$, $\gamma = (a+\mu)/2$. Thus, at $t = \gamma$, we obtain $(a-2t)t + (2a-\mu)\mu = 3(a-\mu)\mu/2$ and this is larger than $(a-\mu)\mu$. $\mathrm{E}W^{NN} > \mathrm{E}W^{CC}$ for all $\sigma^2 < (a-\mu)\mu$.

Third, $\mathrm{E}W^{NC} - \mathrm{E}W^{CC} = [(4a-3\mu)\mu + 2(a+4\mu)t - 11t^2]/18b - \sigma^2/6b \equiv \xi$. By solving $\xi \geq 0$ for t, we have $t^- \leq t \leq t^+$, where $t^-, t^+ \equiv (a + 4\mu \mp \sqrt{a^2 + 52a\mu - 17\mu^2 - 33\sigma^2})/11$. From the discriminant, $(a^2 + 52a\mu - 17\mu^2)/33 - (a-\mu)\mu = (a^2 + 19a\mu + 16\mu^2)/33 > 0$; thus, $\xi = 0$ has two real roots: t^- and t^+. Here, we show that $t^- < 0$ but $\mu < t^+ < \gamma$; that is, there is a range $t^+ \leq t < \gamma$ such that $\mathrm{E}W^{CC} \geq \mathrm{E}W^{NC}$. Since $(a+4\mu)^2 - (\sqrt{a^2 + 52a\mu - 17\mu^2 - 33\sigma^2})^2 = 11[3\sigma^2 - (4a-3\mu)\mu]$ and $\mu(4a-3\mu)/3 - (a-\mu)\mu = a\mu/3 > 0$, $(a-\mu)\mu < \mu(4a-3\mu)/3$. Hence, $t^- < 0$. Subsequently, we obtain $\mu - t^+ = [-(a-7\mu) - \sqrt{a^2 + 52a\mu - 17\mu^2 - 33\sigma^2}\,]/11$. The second term within the square brackets is always positive. By substituting $\sigma^2 = (a-\mu)\mu$ into the second term within the square brackets, we obtain $\sqrt{a^2 + 19a\mu + 16\mu^2}$. Since $\sqrt{a^2 + 52a\mu - 17\mu^2 - 33\sigma^2}$ is monotonically decreasing with σ^2, this second term is positive for all $\sigma^2 < (a-\mu)\mu$. If the first term is non-negative ($-(a-7\mu) \geq 0$), $[-(a-7\mu)]^2 - (\sqrt{a^2 + 52a\mu - 17\mu^2 - 33\sigma^2})^2 = 33[\sigma^2 - 2(a-\mu)\mu]$. Since $(a-\mu)\mu < 2(a-\mu)\mu$, $t^+ > \mu$. Also, if $-(a-7\mu) \leq 0$, $t^+ > \mu$. Therefore, $\mathrm{E}W^{NC} > \mathrm{E}W^{CC}$ for $t \leq \mu$. On the one hand, from the assumption, $\gamma = (a+\mu)/2$ for $t > \mu$. We show that, then, $\mathrm{E}W^{CC} \geq \mathrm{E}W^{NC}$ may hold. $\gamma - t^+ = [3(3a{+}\mu) - 2\sqrt{a^2{+}52a\mu{-}17\mu^2{-}33\sigma^2}\,]/22$. From this, $[3(3a+\mu)]^2 - (2\sqrt{a^2{+}52a\mu{-}17\mu^2{-}33\sigma^2})^2 = 11[7(a{-}\mu)^2 + 12\sigma^2] > 0$. In the range of $t^+ \leq t < \gamma$, $\mathrm{E}W^{CC} \geq \mathrm{E}W^{NC}$. Q.E.D.

Proof of Proposition 4. First, by differentiating world welfare wrt t, we have $\partial\mathrm{E}WW^{NN}/\partial t = -2(a{+}2t)/9b < 0$, $\partial\mathrm{E}WW^{NC}/\partial t = -(a{+}4\mu{+}t)/9b < 0$, and $\partial\mathrm{E}WW^{CC}/\partial t = 0$.

Second, $\mathrm{E}WW^{NC} - \mathrm{E}WW^{CC} = [8a\mu{+}3(\mu^2{+}\sigma^2){-}2(a{+}4\mu)t{-}t^2]/18b$. By solving $\mathrm{E}WW^{NC} \geq \mathrm{E}WW^{CC}$ for t, we have $t \leq t_1 \equiv [\sqrt{a^2{+}16a\mu{+}19\mu^2{+}3\sigma^2} - (a{+}4\mu)](> 0)$. Since $\mu{-}t_1 = a{+}5\mu{-}\sqrt{a^2{+}16a\mu{+}19\mu^2{+}3\sigma^2}$ and $(a{+}5\mu)^2{-}(\sqrt{a^2{+}16a\mu{+}19\mu^2{+}3\sigma^2})^2 = -3\sigma^2 - 6(a{-}\mu)\mu < 0$, $t_1 > \mu$ holds. $\mathrm{E}WW^{NN} - \mathrm{E}WW^{CC} = -2[a(t - 4\mu) + 2(\mu^2 + \sigma^2) + t^2]/9b$. By solving $\mathrm{E}WW^{NN} \geq \mathrm{E}WW^{CC}$ for t, we have $t \leq t_2 \equiv [\sqrt{a^2{+}8\mu(2a{-}\mu){-}8\sigma^2} - a]/2\ (> 0)$. Since $\mu - t_2 = [a + 2\mu - \sqrt{a^2{+}8\mu(2a{-}\mu){-}8\sigma^2}]/2$ and $(a{+}2\mu)^2 - [\sqrt{a^2{+}8\mu(2a{-}\mu){-}8\sigma^2}]^2 = 8\sigma^2 - 12(a{-}\mu)\mu < 0$, $t_2 > \mu$ holds. $t_1 > \mu$ and $t_2 > \mu$ hold, meaning that $\mathrm{E}WW^{NC} > \mathrm{E}WW^{CC}$ and $\mathrm{E}WW^{NN} > \mathrm{E}WW^{CC}$ are in the range $\mu \geq t$.

Finally, from $\mathrm{E}WW^{NN} - \mathrm{E}WW^{NC} = [-3t^2 - 2(a{-}4\mu)t{+}(8a{-}11\mu)\mu{-}11\sigma^2]/18b$, $\mathrm{E}WW^{NN} < \mathrm{E}WW^{NC}$ holds if $\mu \leq a/4$ and $\sigma^2 \geq (8a{-}11\mu)\mu/11$. $\mathrm{E}WW^{NN}$ and $\mathrm{E}WW^{NC}$ decrease with t, meaning that $t = 0$ maximizes $\mathrm{E}WW^{NN}$ and $t = \mu$ minimizes $\mathrm{E}WW^{NC}$ in the range $\mu \geq t$. Simple algebra yields $\mathrm{E}WW^{NC}|_{t=\mu} - \mathrm{E}WW^{NN}|_{t=0} = [2(a{-}\mu)(4a{-}\mu){+}11\sigma^2]/18b{-}4a^2/9b = [11\sigma^2{-}2(5a{-}\mu)\mu]/18b$. From this, $\mathrm{E}WW^{NC}|_{t=\mu} \geq \mathrm{E}WW^{NN}|_{t=0}$ if $\sigma^2 \geq 2(5a{-}\mu)\mu/11$. To satisfy $(a{-}\mu)\mu > 2(5a{-}\mu)\mu/11$, we need $\mu < a/9$. Furthermore, $(8a{-}11\mu)\mu/11 - 2(5a{-}\mu)\mu/11 = -(2a{+}9\mu)\mu/11 < 0$. Therefore, if $\mu < a/9$ and $\sigma^2 \geq 2(5a - \mu)\mu/11$, the mixed regime maximizes world welfare. Q.E.D.

Proof of Proposition 6. From (19)–(21), we solve $\mathrm{E}\bar{\pi}_1^{NN} - \mathrm{E}\bar{\pi}_1^{CN} \geq 0$ and $\mathrm{E}\bar{\pi}_2^{NN} - \mathrm{E}\bar{\pi}_2^{NC} \geq 0$ for σ_i^2: $\sigma_i^2 \leq (a{-}\mu)(\mu{-}t) \equiv \phi_N$. Furthermore, we solve $\mathrm{E}\bar{\pi}_1^{NC} - \mathrm{E}\bar{\pi}_1^{CC} \geq 0$ and $\mathrm{E}\bar{\pi}_2^{CN} - \mathrm{E}\bar{\pi}_2^{CC} \geq 0$ for σ_i^2: $\sigma_i^2 \leq Cov + (a{-}t)(\mu{-}t) \equiv \phi_C$. We compare ϕ_C with ϕ_N and obtain $\phi_C - \phi_N = Cov + (\mu{-}t)^2 \geq 0$. Hence, firms tend to comply with the ROO when the rival does not comply. Next, we consider the case $\sigma_i > 0$, $Cov = \varepsilon$, and $t = \mu - \varepsilon$, where ε takes a sufficiently small positive value. Then, the inequalities in the above are not satisfied. Hence, regardless of the rival firm's decision, both firms always comply with the

ROO. Q.E.D.

Illustration of Figure 4. When $\mu > t$, because CC does not appear, we consider $\mathrm{E}CS^{NN}$ and $\mathrm{E}CS^{NC}$. First, if $\sigma^2 \leq (a-\mu)(\mu-t)$, the no-complier regime appears and if $\sigma^2 > (a-\mu)(\mu-t)$, the mixed regime appears. Second, from (11) and (13), $\mathrm{E}CS^{NN} - \mathrm{E}CS^{NC} = [-\sigma^2 + (4a-3t-\mu)(\mu-t)]/18b$. Since $4a - 3t - \mu > 0$ and $\mu - t > 0$, the following relation holds: $\mathrm{E}CS^{NN} \geq (<)\ \mathrm{E}CS^{NC}$ for $\sigma^2 \leq (>)\ (4a-3t-\mu)(\mu-t)$. From $t, \mu < \gamma$, $(4a-3t-\mu)(\mu-t) > (a-\mu)(\mu-t)$. We verify the ranking between $(a-\mu)\mu$ and $(4a-3t-\mu)(\mu-t)$. The difference in those is $(a-\mu)\mu-(4a-3t-\mu)(\mu-t) = -3a\mu+2(2a+\mu)t-3t^2$. By solving $-3a\mu + 2(2a+\mu)t - 3t^2 \geq 0$ wrt t, we have $[(2a+\mu) - \sqrt{(a-\mu)(4a-\mu)}] \equiv \tilde{t} \leq t$. Since $0 < \tilde{t} < \mu,\ \mathrm{E}CS^{NN} < \mathrm{E}CS^{NC}$ if $(4a-3t-\mu)(\mu-t) < \sigma^2 < (a-\mu)\mu$.

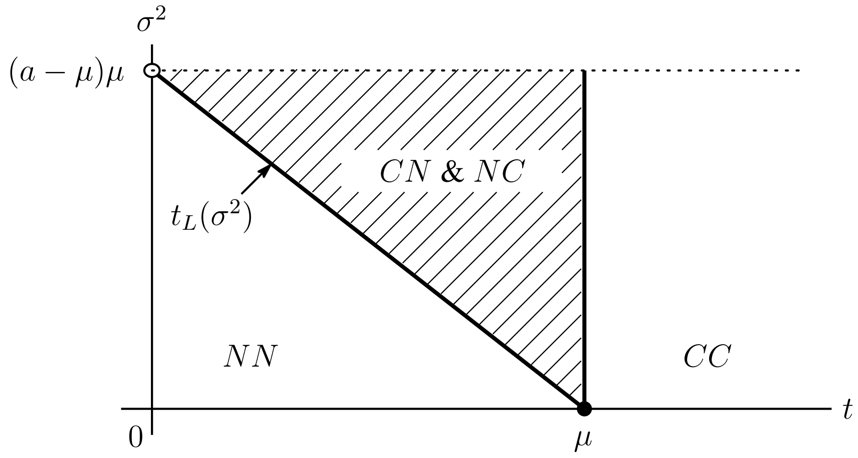


Figure 1: Equilibrium outcomes in the t-σ^2 plane (two firms)

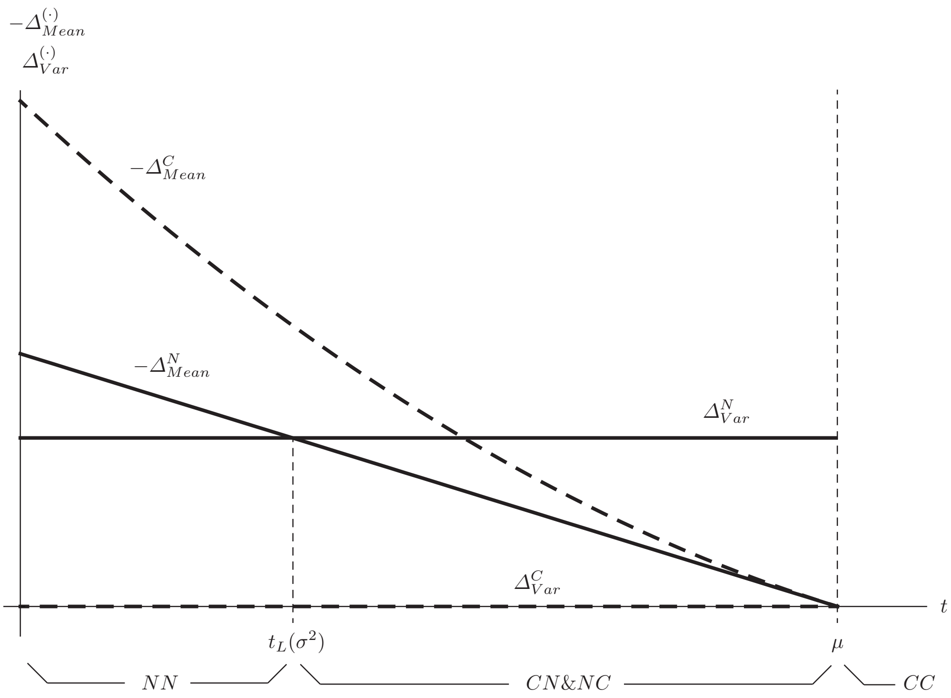
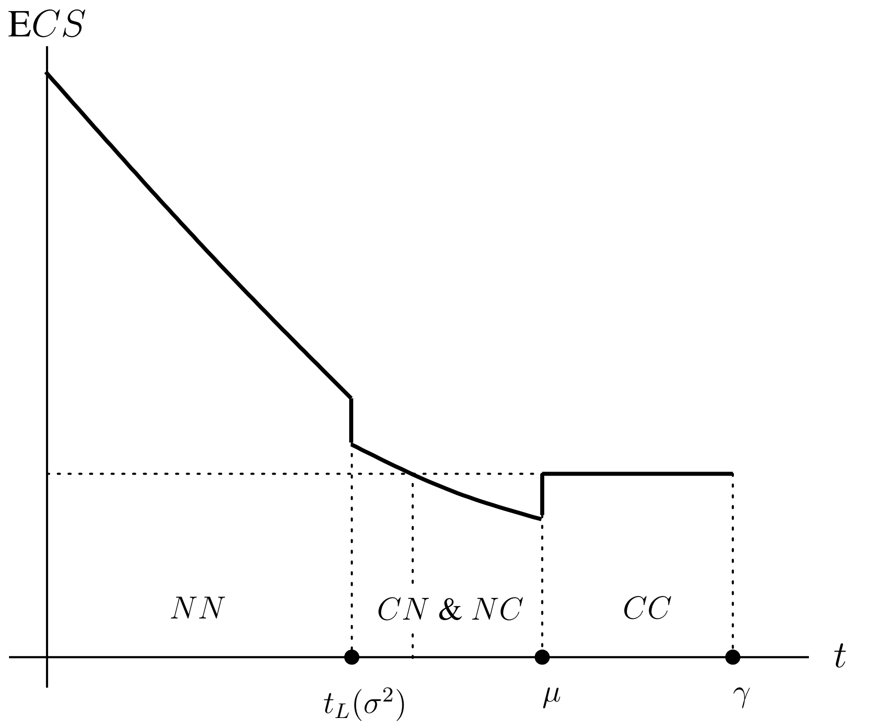
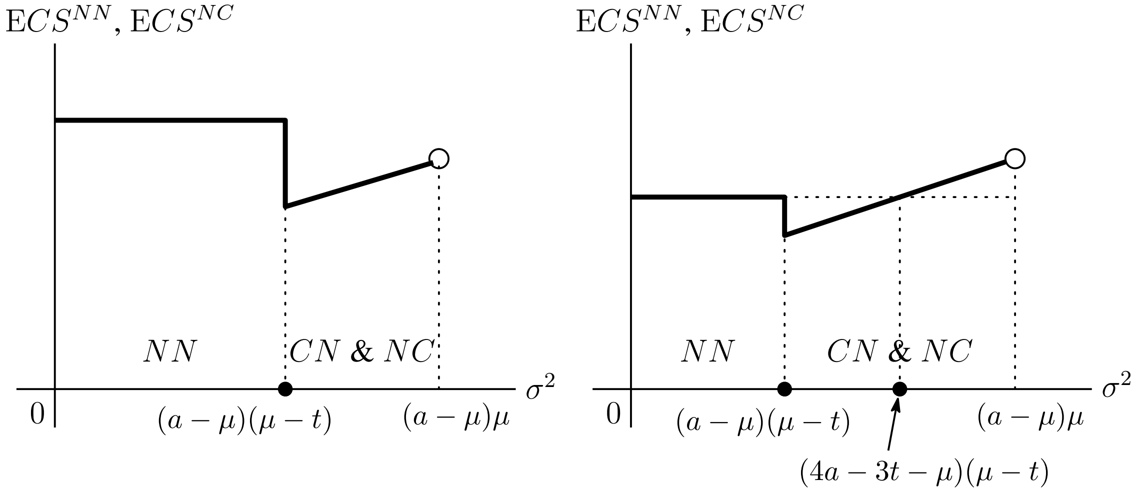


Figure 2: Effects of switching strategy from N to C



Note: $\mathrm{E}CS^{NN} > \mathrm{E}CS^{NC} = \mathrm{E}CS^{CN}$ at $t = t_L(\sigma^2)$ but $\mathrm{E}CS^{NN} < \mathrm{E}CS^{NC} = \mathrm{E}CS^{CN}$ at $t = \mu$.

Figure 3: Effects of regime switches on consumer surplus



Panel (a): $t \leq \tilde{t}$

Panel (b): $t > \tilde{t}$

Figure 4: Low external tariff case ($\mu > t$)

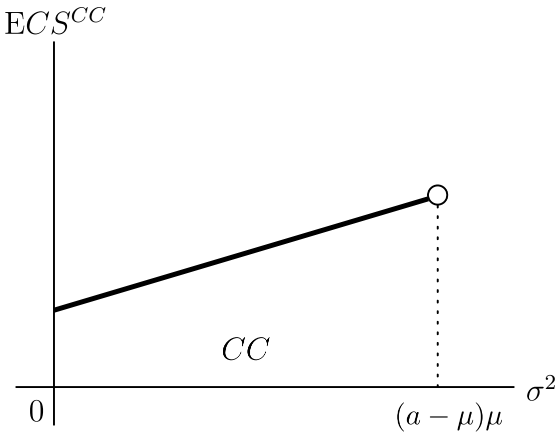


Figure 5: High external tariff case ($\mu \leq t$)

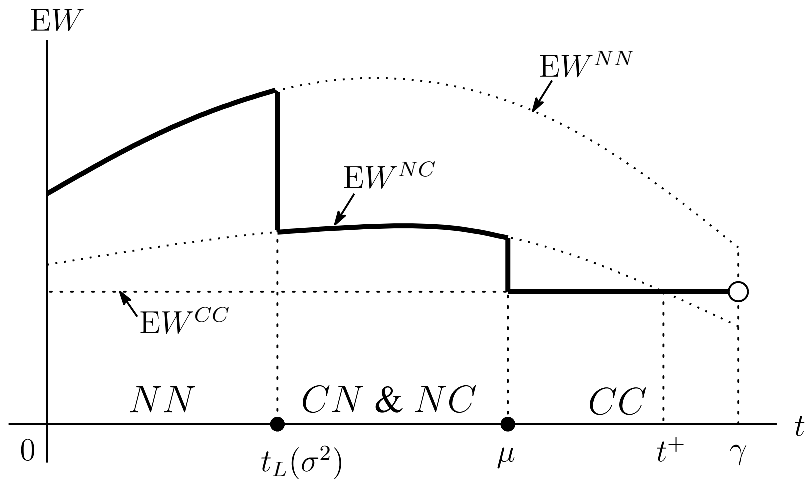
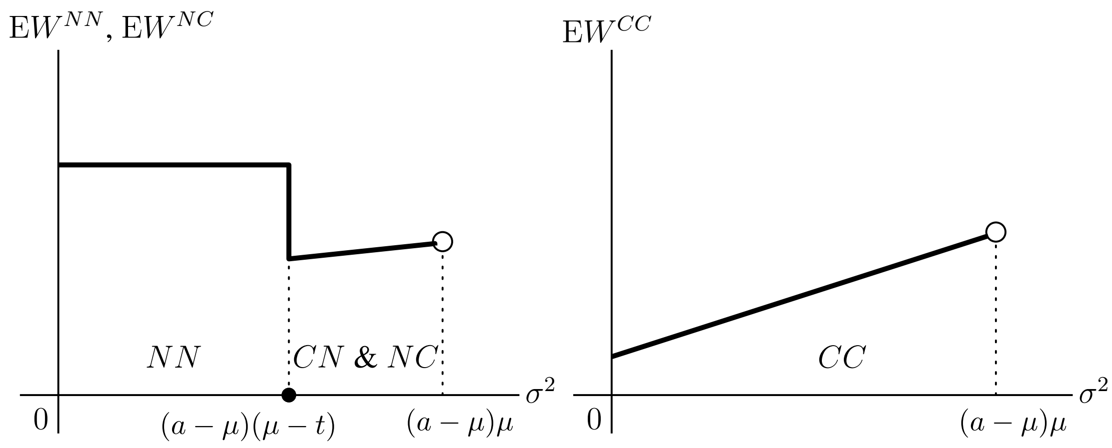


Figure 6: Illustration of Proposition 3



Panel (a): $\mu > t$

Panel (b): $\mu \leq t$

Figure 7: Consuming country’s welfare and variance

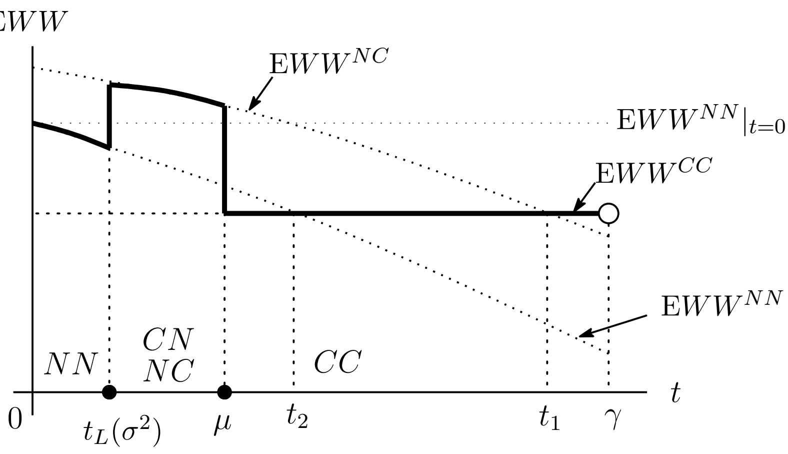


Figure 8: Illustration of Proposition 4

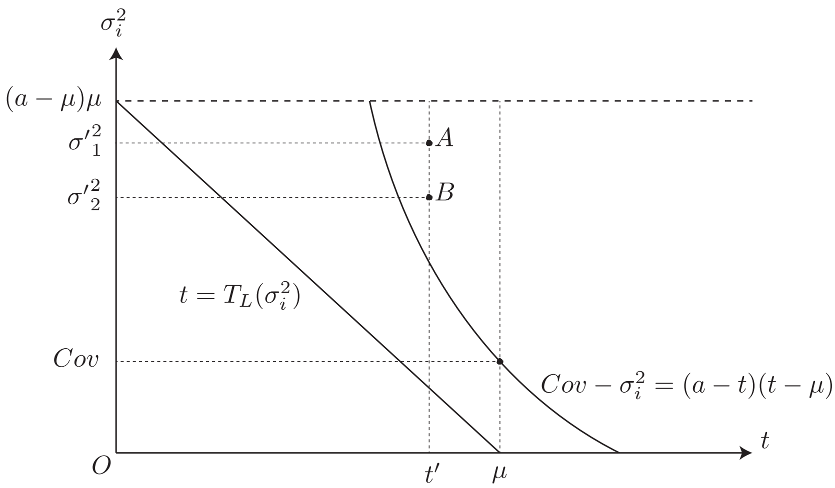


Figure 9: Decision for compliance