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Antidumping as Strategic Trade Policy Under Asymmetric Information

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Abstract

In the last two decades, trade liberalization under GATT/WTO has been partly offset by an increase in antidumping protection. Economists have argued convincingly that this is partly due to the inclusion of sales below cost in the definition of dumping during the GATT Tokyo Round. The introduction of the cost- based dumping definition gives regulating authorities a better opportunity to choose protection according to their liking. This paper investigates the domestic government's antidumping duty choice in an asymmetric information framework where the foreign firm's cost is observed by the domestic firm, but not by the government. To induce truthful revelation, the government can design a tariff schedule, contingent on firms' cost reports, accompanied by a threat to collect additional information for report verification (i.e., auditing) and, in case misreporting is detected, to set penalty duties. We show that depending on the concrete assumptions, the domestic government may not only be able to extract the true cost information, but also succeeds in implementing the full-information, governmental welfare-maximizing duty. In this case, the antidumping framework within GATT/WTO does not only offer the means to pursue strategic trade policy disguised as fair trade policy, but it also helps overcome the informational problems with regard to correctly determining the optimal strategic trade policy. Keywords:antidumping duties, asymmetric information, trade protection, strategic trade policy.

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1. Introduction

Trade liberalization under GATT/WTO has been an impressive success. Not only have average tariff levels been lowered considerably, but additional product categories not included in previous trade liberalization agreements have also recently become subject to the general liberalization process, e.g., agricultural products and textiles. Yet, right from the beginning, trade liberalization under GATT was not without exceptions. In fact, one major reason why the number of countries signing off on the GATT increased so considerably was probably that the agreement contained numerous provisions to allow participants to "withdraw – or cease to apply – their normal obligations in order to protect (safeguard) certain overriding interests." (Hoekman and Kostecki, 2001, p. 303). One such exception provision that has proved especially popular are antidumping measures. Article VI of GATT stipulates that member countries can impose antidumping duties on products that are imported at below-normal value (i.e., either below the price in the exporting-country or third-country market or below production cost plus reasonable additions for sales cost and profit) and cause material injury to a domestic industry. In this paper, we investigate in how far antidumping may be (ab)used to conduct strategic trade policy.

During the first decades of the GATT, antidumping duties were used rather infrequently. This changed with the completion of the GATT Tokyo Round in 1979, when the antidumping statute was amended. First, the definition of selling below fair or normal value was extended to include sales below cost; today, the "fair/normal value" is more likely to be a value constructed from cost estimates and "reasonable" additions rather than being an observable market price. Moreover, it was no longer deemed necessary to prove that dumping was the principal cause of material injury (Blonigen and Prusa, 2003). These changes eventually resulted in a veritable antidumping "boom". Whereas the successful completion of the Uruguay Round led to considerable progress in bringing down average tariff rates and increasing the product range to which trade liberalization applied, a parallel movement to increase trade protection under the cloak of "fair trade" took place: From 1995 to 2006, the number of antidumping measures increased dramatically, reaching an all-time high with 227 antidumping measures reported by WTO members in 2000. In addition, the

number of users increased dramatically as well, with developing countries starting to add antidumping to their trade policy toolkit and India becoming the most frequent antidumping user (WTO information as of January 2009).[1]

It has been well recognized by trade economists that "dumping" is a flexible term and can be used rather arbitrarily to impede foreign competition in the domestic market, thus creating a new protectionism under the auspices of GATT/WTO (Blonigen and Prusa, 2003). In particular, the introduction of the cost-based dumping definition during the GATT Tokyo Round has increased the discretionary leeway for the antidumping authority to determine dumping and the dumping margin. For example, Lindsey and Ikenson (2003) and Blonigen (2006) explain in some detail how the existing rules can be abused to regularly find pricing below normal value if this is politically desired. It thus seems reasonable to assume that antidumping may be used to pursue strategic trade policy, given that antidumping is especially prevalent in oligopolistic industries. According to the definition by Brander (1995, p.1397), strategic trade policy is "trade policy that conditions or alters a strategic relationship between firms". Under oligopoly, the optimal trade policy is usually not free trade due to a rent-shifting argument. However, calculating the size and even the type of the optimal trade policy instrument is difficult because the government typically does not possess the necessary market- and firm-specific information.

In this paper, we investigate how the domestic government, i.e., the antidumping authority, can use the antidumping procedure for optimal mechanism design to solicit the information necessary for calculating the optimal strategic trade policy. To this purpose, we consider the market for a good in which a domestic firm and a foreign firm operate and assume that the optimal strategic trade policy under perfect information would be an import tariff[2] which raises domestic profit and tariff revenue at the expense of domestic consumers and the foreign firm's profit. To calculate the optimal strategic import tariff, the domestic government needs information about the foreign firm's cost. In our model, we assume that the domestic government a priori does not have this cost information, but the analysis also readily carries over to the

[1] `http://www.wto.org/english/tratop_e/adp_e/adp_e.htm#statistics`

[2] For conditions, see, e.g., Brander and Spencer (1984), Dixit (1984), and Helpman and Krugman (1989).

case that other market or firm-level information is known to the firms, but not to the authorities, e.g., demand information or information about the form of strategic interaction between firms. Since the government does not have the cost information, but the foreign firm and maybe even the domestic firm does, it makes sense to consider the question of optimal antidumping duties in an asymmetric information framework. In particular, we discuss how the domestic antidumping authority can design an optimal mechanism to obtain the foreign cost information, using antidumping duties and audits as instruments.

The topic of antidumping under asymmetric information is not completely novel to the literature. Kohler and Moore (2001) also model auditing during an antidumping investigation, but they assume perfect competition, and the asymmetric information in their paper is about domestic cost and whether or not material injury has occurred. In their context, the domestic government is not interested in active trade policy per se, but has to employ a tariff in case the domestic industry is truly injured by foreign competition. In our paper, in contrast, the government uses antidumping as a convenient means to pursue strategic trade policy. Our paper is probably most closely related to Cheng, Qiu, and Wong (2001) who also consider antidumping as a type of strategic trade policy. Our paper is different from theirs, however, with regard to the instruments at the authority's disposal. Cheng et al. (2001) allow for lump sum payments to firms, whereas we, in line with reality, do not allow such payments as an instrument to extract the true cost information.[3] Instead, the authority can use the antidumping duties and the threat of audits at the foreign firm's premises, which are allowed according to GATT/WTO rules, to find out about foreign cost.

We show that in general, the instruments available to the domestic authority in the course of an antidumping investigation are fully sufficient to obtain the correct cost information. Moreover, under certain assumptions, the domestic government does not

[3]Payments from firms to the antidumping authority would be viewed as attempted bribery and are thus not allowed. Payments from the authority to firms are considered as trade-distorting subsidies forbidden under the WTO. For example, the Byrd amendment, that distributed antidumping revenue to petitioning firms in the U.S., was ruled in violation with WTO rules in 2003 and had to be scrapped.

only extract the true cost information, but also succeeds in implementing the full-information, governmental welfare-maximizing duty. In this case, the antidumping framework within GATT/WTO does not only offer the means to pursue strategic trade policy disguised as fair trade policy, but it also helps overcome the informational problems with regard to correctly determining the optimal strategic trade policy. This formerly ignored aspect of antidumping may make antidumping more attractive for governments eager to employ strategic trade policy and may thus pose a greater danger to trade liberalization than previously thought.

The remainder of this paper is organized as follows: In section 2, we set forth the theoretical model framework. In sections 3, 4, and 5, we discuss the solution to the government's mechanism design problem under varying assumptions about how much leeway GATT/WTO regulations provide with respect to the duty choice, but maintaining the assumption that auditing is perfect and antidumping duties and auditing probabilities are contractible. In section 6, we discuss in how far the presented solutions are feasible when contractibility does not hold, and in section 7 we investigate the consequences of an imperfect auditing technology. Section 8 concludes. Proofs can be found in Appendix A and diagrams in Appendix B.

2. The Model

Consider a country with two firms, one domestic and one foreign, in the market for a good. The foreign firm has constant marginal cost c. The realization of this cost parameter is known to both firms,[4] but the government/domestic antidumping authority only knows that c equals $\bar{c}$ with probability α and $\underline{c}$ with probability $1-\alpha$, where $\alpha \in (0,1)$ and $\underline{c} < \bar{c}$. Apart from the foreign cost information, the information sets of authority and firms are identical. Alternatively, we could also consider asymmetric information about demand or some other parameter necessary to calculate the optimal strategic trade policy. The analysis would be analogous. Choosing the cost parameter as the parameter of interest seems the most natural choice, however, given the prevalence of the cost-based antidumping definition in antidumping investigations. To calculate the dumping margin, the antidumping authority certainly needs

[4]Section 5 also covers the case when only the foreign firm knows c.

to know cost, and thus it has a legitimate reason to investigate the cost parameter during an antidumping investigation; but at the same time, this information also proves useful for calculating any optimal strategic trade policy.

We analyze the interaction between the antidumping authority and the two firms in one given period. We assume that, in the previous period, a certain price p_0 for the foreign good was observed and is now the object (the alleged below fair value price) of the dumping investigation. According to the cost-based dumping definition, dumping has occurred if p_0 lies below the foreign firm's marginal cost c. The dumping margin (abstracting from sales and profit surcharges to the cost parameter) is $m(c) = \max\{c - p_0, 0\}$. This dumping margin at time $t-1$ provides the basis for the antidumping duty in time t. The timing is thus similar to the one in Cheng et al. (2001). Throughout, we assume that the dumping margin is indeed strictly positive and that the antidumping authority has sufficient leeway to claim material injury to the domestic industry (or the lack thereof) from dumping, so that antidumping duties are feasible, but at the same time need not be imposed. The realization of c cannot be inferred from the price observation, possibly because of a random element in the price (we provide an example below). The domestic firm has filed a dumping complaint with the domestic authority, contending that the foreign firm has sold its products below cost. The domestic firm's goal is to receive protection in form of an antidumping duty t and increase its expected profit $\Pi_d(c,t)$ which is strictly increasing in t as long as $t \leq t_0(c)$ where $t_0(c)$ is the tariff at which the foreign firm's expected profit becomes 0. Similarly, the foreign firm's expected profit $\Pi_f(c,t)$ is strictly decreasing in t for $t \leq t_0(c)$.

The domestic authority uses the antidumping framework for strategic trade policy purposes, i.e., it wishes to maximize an objective (welfare) function $W(c,t)$ which is strictly concave in t, for example the expectation of consumer surplus, domestic profit, and tariff revenue conditional on c, or a weighted sum thereof.[5] As a benchmark, denote by $t^*(c)$ the tariff that maximizes $W(c,t)$. We are going to call this tariff the full-information optimal tariff. It is the tariff that the authority

[5]An inclusion of consumer surplus in the objective function is by no means necessary for our results, and we only explicitly include it in the numerical example which we provide to illustrate our results.

would implement if the information sets of authority and firms were equal (i.e., all parties know c, but it is still possible that some other variables as, e.g., demand, are random as long as everybody has the same distributional information). We assume throughout that $t^*(c) > 0$. Furthermore, we restrict attention to $t^*(c)$ being strictly decreasing in c, i.e. $\frac{\partial^2 W}{\partial t \partial c} < 0$, in order to reduce the number of cases that need to be discussed. The analysis for the case that $t^*(c)$ is increasing in c can be conducted analogously.

Throughout, we are going to further illustrate our general findings by means of a simple example with linear market demand and Cournot competition which is described below. The reader should note that our general model neither assumes linearity of demand nor Cournot competition.[6]

Example 2.1. *Let the market demand for a homogeneous good be linear of the form* $Q = \tilde{a} - p$ *where* Q *is total output defined as sum of domestic firm's output* q_d *and foreign firm's output* q_f *and* $\tilde{a} = a + \epsilon$ *is subject to a random shock* ϵ *which is distributed with probability density function* f_ϵ *and an expected value of 0. Let the domestic firm's marginal cost be* k*. Firms compete Cournot style and set quantities before the realization of* $\tilde{a}$*. Hence, the Cournot-Nash quantities are non-random and given by* $q_d = (a + c + t - 2k)/3$ *for the domestic firm and* $q_f = (a + k - 2c - 2t)/3$ *for the foreign firm, leading to a market price of* $p = (a + k + c + t)/3 + \epsilon$*. If* ϵ *is sufficiently negative, it is thus indeed possible that the equilibrium price lies below the foreign firm's marginal cost* c*, leading to unintentional or cyclical dumping according to the cost-based dumping definition (Cheng et al., 2001).*[7] *Assume the authority maximizes domestic welfare defined as sum of expected consumer surplus, expected domestic firm's profit, and tariff revenue, i.e.,*

$$W(c,t) = V(c,t) + \Pi_d(c,t) + T(c,t) \tag{2.1}$$

where $V = \int (\tilde{a} - p)Q/2 f_\epsilon d\epsilon = (2a - k - c - t)^2/18$ *denotes expected consumer surplus,* $\Pi_d = \int (p - k) q_d f_\epsilon d\epsilon = (a - 2k + c + t)^2/9$ *the expected domestic profit,*

[6] In particular, antidumping may alter the strategic interaction between firms, as originally shown by Staiger and Wolak (1989). Our general model encompasses this possibility as well.

[7] Since the domestic authority uses antidumping for strategic trade policy purposes rather than to counter deliberate dumping, whether or not dumping was intended is not of importance.

and $T = tq_f = t(a + k - 2c - 2t)/3$ *the tariff revenue under Cournot duopoly. The full-information optimal tariff*[8] *that maximizes* (2.1) *is then given by* $t^*(c) = (a-c)/3$ *and is thus decreasing in* c.[9]

However, in line with reality, we assume that the authority does not a priori have perfect information about foreign cost. Moreover, in the real world, trade policy choices may be restricted under GATT/WTO. Therefore, to find out the foreign cost parameter c, the authority uses an antidumping procedure which is designed to comply with GATT/WTO regulations. The antidumping investigation is initiated by the home firm's filing a dumping complaint and providing information about the alleged dumping. More specifically, we assume that the domestic firm provides information about the foreign firm's cost parameter c. Once the petition has passed a preliminary plausibility check, the authority is required to investigate the allegations according to article 5 of the Uruguay Round Antidumping Agreement (GATT, 1994). An integral part of these investigations consists of having the foreign firm fill out a detailed questionnaire, which, for the purposes of our model, we interpret as asking the foreign firm for its cost information. According to article 6.7 of the Antidumping Agreement (GATT, 1994), "in order to verify information provided or to obtain further details, the authorities may carry on investigations in the territory of other members as required, provided they obtain the agreement of the firms concerned". Such an audit at the foreign firm's premises causes a cost $M > 0$ for the authority. For now, we assume that such an audit always reveals the true cost parameter (perfect auditing). The case of imperfect auditing is analyzed in section 7. It is important to notice that the foreign firm cannot be forced to allow an audit. However, if it refuses an

[8]Our situation where a domestic government uses a tariff to strategically alter the interaction between a domestic and a foreign firm in the domestic market should not be confused with a model where a government wants to shift profits from a foreign firm to a domestic exporter in a third-country Cournot duopoly market (Brander and Spencer, 1985). In this latter case, the optimal strategic trade policy would be an export subsidy.

[9]If, however, the antidumping authority maximizes a weighted sum of consumer surplus and tariff revenue on the one hand and domestic profit on the other hand, $t^*(c)$ is strictly increasing in c if the weight β on the domestic profit lies between 5/2 and 11/2. If β is even higher, the authority would want to set a prohibitive tariff.

audit, the authority can use a "facts available" policy which regularly leads to higher antidumping duties as in the case when the foreign firm complies with the investigation. We are going to call these higher tariffs, which are imposed either because the foreign firm did not choose to provide all requested information in the antidumping investigation or because the provided information turned out to be incorrect in an audit, punishment tariffs.

The auditing probability $\theta(c_d, c_f)$ itself is contingent on the cost reports c_d and c_f by the domestic and the foreign firm, respectively. Complementing the audit probability, the authority can use the antidumping duty itself as instrument. In the following, we denote by $t(c_d, c_f)$ the antidumping duty ("normal tariff") that is imposed when the cost reports are c_d and c_f, respectively, and no audit has taken place, and by $\tilde{t}(c_d, c_f|c)$ the antidumping duty ("punishment tariff", such as a higher tariff from using "facts available") that is imposed when the cost reports are c_d and c_f and an audit is conducted that reveals that the true cost parameter equals c. We assume that $\tilde{t}(c, c|c) = t(c, c)$, i.e., if an audit shows that both firms have reported truthfully, the normal tariff rate applies. The tariff functions and auditing probabilities might need to be chosen to meet certain regulations, e.g., tariffs might have to be at or below the dumping margin $m(c)$. We allow for different possibilities in this respect, discussed in more detail below.

Without an incentive-compatible mechanism in place, the domestic firm will report c_d such that the maximum tariff is obtained and the foreign firm will report c_f such that the minimum tariff is obtained. We show that, depending on the concrete assumptions, the authority may take advantage of this conflict of interests and may design a mechanism that does not only lead to the truthful revelation of c, but also to the implementation of the full-information optimal tariff $t^*(c)$.

Initially, we assume that tariffs and auditing probabilities are contractible. In this case, timing is as follows. First, the foreign firm's price p_0 of the last period is observed by everyone. Then, the authority commits to the tariff schedules $t(c_d, c_f)$, $\tilde{t}(c_d, c_f|c)$ and auditing probabilities $\theta(c_d, c_f)$. Afterwards, the domestic firm decides whether to file an antidumping petition, which includes its cost report c_d. In case a petition arrives, the authority asks the foreign firm to hand in its cost report c_f.

The authority then audits with probability $\theta(c_d, c_f)$ and implements antidumping measures according to the ex-ante announced schemes. Finally, firms set their decision variables (i.e., choose production quantities in the example), followed by the resolution of uncertainty (i.e., the realization of the demand shock in the example).

However, contractibility of tariff schemes and auditing probabilities might not always be given. In particular, the contractibility of auditing may be a strong assumption since compliance with an auditing scheme is particularly difficult to verify.[10] This is problematic if the ex-ante announced tariff schemes and auditing probabilities are not optimal ex-post, i.e., once the authority is informed about the foreign firm's cost. Then, the authority would want to deviate from its ex-ante announcements. We therefore discuss the implications of non-contractibility in section 6.

In how far the real existing dumping margin may constitute an upper bound for antidumping duties and thus strategic trade policy is debatable. The idea of maximum discretion is reflected in works such as Kolev and Prusa (2002) where an optimal antidumping duty can be set regardless of whether dumping has actually occurred. Others, such as Cheng et al. (2001), assume that the real existing dumping margin is indeed the upper bound for any antidumping duty. When looking at this question from a contract theory perspective, the level of discretion that the antidumping authority has when imposing an antidumping duty actually depends on the degree to which the cost parameter is verifiable by a third party, i.e. an independent court. We distinguish between three cases. In case 1, c is non-verifiable and the authority is thus completely free in designing an antidumping procedure and implementing any arbitrary tariff. By contrast, in case 2, c is verifiable so that the authority cannot choose tariffs that are above the *true* dumping margin. Case 3 lies in-between the previous two. In this case, c is not verifiable, but the authority needs to provide some proof of the realization of c, such as a firm's report, to defend its choice of antidumping duty. In this case, it can implement all tariffs that are below or at the maximum dumping margin *reported* by either the domestic or the foreign firm.

[10] Even if inspectors arrive at the foreign firm's premises, it is hard to verify how much effort they put into the investigation.

In the following, we will demonstrate how the authority can take advantage of the antidumping procedure and induce the firms to share the information about foreign cost. We will also discuss whether the antidumping duties will equal the full-information tariffs.

3. Case 1: Complete freedom of designing an antidumping mechanism

In this section, we assume that the authority has complete freedom in choosing the tariff schedule and the auditing probabilities. In particular, after using the antidumping procedure as a pretext to find out the cost parameter c, the authority is not bound by the actual dumping margin when deciding on a tariff. This will be the case if the true cost parameter c cannot be verified by an independent third party.[11] Then, the authority can distort the obtained information in such a way as to construct a dumping margin according to its liking, and this distortion cannot be proven in an independent investigation. This is clearly a strong assumption and will be dropped in the next sections, but seems a good starting point given the diverging views on how much discretion the antidumping authority really has in determining the dumping margin.

We assume that the authority wishes to induce truthful reporting of the foreign firm's cost parameter by both firms. Afterwards, we will see that doing so is indeed optimal from the authority's point of view. We implement truth-telling as a pure-strategy Nash equilibrium. The authority thus chooses tariffs $t(c_d, c_f)$ and $\tilde{t}(c_d, c_f|c)$ as well as auditing probabilities $\theta(c_d, c_f)$ to maximize the expectation of welfare $W(c, t(c, c))$ minus auditing cost M

$$\alpha[W(\bar{c}, t(\bar{c}, \bar{c})) - \theta(\bar{c}, \bar{c})M] + (1-\alpha)[W(\underline{c}, t(\underline{c}, \underline{c})) - \theta(\underline{c}, \underline{c})M], \tag{3.1}$$

subject to the constraints that for every $c, \tilde{c} \in \{\underline{c}, \bar{c}\}$ and $\tilde{c} \neq c$ we have

$$\Pi_d(c, t(c, c)) \geq [1 - \theta(\tilde{c}, c)]\Pi_d(c, t(\tilde{c}, c)) + \theta(\tilde{c}, c)\Pi_d(c, \tilde{t}(\tilde{c}, c|c)), \tag{3.2}$$

$$\Pi_f(c, t(c, c)) \geq [1 - \theta(c, \tilde{c})]\Pi_f(c, t(c, \tilde{c})) + \theta(c, \tilde{c})\Pi_f(c, \tilde{t}(c, \tilde{c}|c)). \tag{3.3}$$

[11] Or, equivalently, the foreign firm has no means to enforce a tariff below the actual dumping margin.

The first set of constraints (3.2) are the incentive compatibility constraints for truthful reporting by the domestic firm. They state that, given that the foreign firm makes a truthful report, the domestic firm must also prefer to tell the truth. Truthtelling yields the expected profit $\Pi_d(c, t(c, c))$. Lying entails an audit with probability $\theta(\tilde{c}, c)$. The audit reveals misreporting by the domestic firm and leads to the tariff $\tilde{t}(\tilde{c}, c|c)$. If in spite of diverging reports the authority does not audit, the tariff is $t(\tilde{c}, c)$. Similarly, the second set of constraints (3.3) are the incentive compatibility constraints for the foreign firm. We omit the participation constraints for the firms because in our model, they are very easy to satisfy since a non-reporting firm can be punished by a sufficiently high (for the foreign firm) or sufficiently low tariff (for the domestic firm): The authority can always ensure the foreign firm's participation by punishing non-participation with a tariff that is weakly higher than the tariff $t(c, c)$. Similarly, the domestic firm's participation constraint is unproblematic: The domestic firm always (weakly) benefits from initiating an antidumping investigation since the implemented tariff will be non-negative.[12] To simplify the discussion, we assume that whenever any of the incentive compatibility constraints bind, a firm will choose truth-telling over lying.[13]

To solve the authority's optimization problem, first note that all constraints are easily satisfied by the following auditing and tariff scheme. The authority audits if and only if reports do not coincide, i.e., $\theta(c_d, c_f) = 1$ if $c_d \neq c_f$ and $\theta(c_d, c_f) = 0$ if $c_d = c_f$. The normal tariffs are set equal to the perfect-information tariffs when reports are identical, i.e., $t(c_d, c_f) = t^*(c_d) = t^*(c_f)$ if $c_d = c_f$. Finally, punishment tariffs for a lying domestic firm are weakly lower and those for a lying foreign firm are weakly higher than the normal tariff rates, i.e., $\tilde{t}(c_d, c|c) \leq t^*(c)$ if $c_d \neq c$ and

[12] We are abstracting from participation costs here. Of course, writing an antidumping petition is costly for the domestic firm. Similarly, providing all the information requested in an antidumping investigation entails cost for the foreign firm. If the domestic firm does not file a complaint, however, an antidumping investigation will not take place, so it makes sense in our analysis to assume that the domestic firm's participation constraint is fulfilled. For an empirical investigation on the determinants of foreign firm cooperation in antidumping investigations, see Moore and Fox (2007).

[13] This simplifying assumption avoids cumbersome discussions of multiple equilibria in case that the punishment tariffs cannot differ from the normal tariffs.

$\tilde{t}(c, c_f|c) \geq t^*(c)$ if $c_f \neq c$. In anticipation of a possible commitment problem on the side of the authority under non-contractibility of tariff schemes, we set the punishment tariffs equal to the normal tariff levels $t^*(c)$. Then, the implementation of punishment tariffs is credible even if they are not contractible, because they are ex-post optimal from the authority's point of view.

Given these auditing probabilities and tariffs, truthful reporting of both firms constitutes an equilibrium. It does not pay for either firm to misreport cost because if it does so unilaterally, an audit will uncover the lie for sure and no tariff advantages can be gained by misreporting. Consequently, identical reports arrive in equilibrium, and the authority does not need to incur any auditing costs. In addition, the perfect-information tariffs $t^*(c)$ are implemented. Thus, the proposed combination of tariffs and auditing probabilities is optimal from the authority's point of view. For further reference, we call this approach *mechanism A*. We summarize our results in the following proposition.

Proposition 3.1. *Consider the case where the actual dumping margin does not limit the authority's choice of antidumping duty. The following incentive-compatible mechanism A is optimal from the authority's perspective: If* $c_d = c_f$*, the auditing probability is* $\theta_A(c_d, c_f) = 0$ *and the antidumping duty is* $t_A(c_d, c_f) = t^*(c_d) = t^*(c_f)$*. If* $c_d \neq c_f$*,* $\theta_A(c_d, c_f) = 1$ *and* $\tilde{t}_A(c_d, c_f|c) = t^*(c)$*.*

In equilibrium, both firms report truthfully and the full-information tariffs $t^*(c)$ *will be implemented; moreover, auditing never takes place and hence does not cause any costs. Governmental welfare is thus given by* $W(c, t^*(c))$*, i.e., equals welfare under perfect information.*

Example 3.1. *In our example, mechanism A consists of normal tariffs* $t_A(c, c) = (a - c)/3$*, punishment tariffs* $\tilde{t}_A(c, \tilde{c}|c) = \tilde{t}_A(\tilde{c}, c|c) = (a - c)/3$ *and auditing probabilities* $\theta_A(c_d, c_f) = 0$ *if* $c_d = c_f$ *and* $\theta_A(c_d, c_f) = 1$ *otherwise.*

4. Case 2: Tariffs at or below the true dumping margin

In this section, we turn to the counterpart of case 1. We now assume that the true cost parameter c is verifiable by an independent third party. This implies that the authority cannot conceal, distort, or misinterpret the information obtained

during the antidumping investigation. Thus, whenever the authority tries to impose a tariff exceeding the dumping margin, the foreign firm will request that its government file a trade dispute, which should be successful since the antidumping duty is indeed excessive.[14] Consequently, the actual dumping margin places an upper bound on the attainable antidumping duty since according to GATT/WTO, the authority cannot set antidumping duties beyond the dumping margin $m(c) = \max\{0, c - p_0\}$. Hence, we define the *constrained optimal antidumping duty* as $t_m^*(c) := \min\{t^*(c), m(c)\}$. Concerning the auditing procedure, we retain the assumption that the authority is free to choose the auditing probabilities $\theta(c_d, c_f)$.[15]

Analogously to case 1, we start the analysis under the assumption that the authority wishes to induce both firms to tell the truth, which will then prove to be the optimal approach. The authority's optimization problem is also very similar to the one in case 1. The authority again maximizes the objective function (3.1) under the incentive compatibility constraints (3.2) and (3.3). In addition, it has to take into account the constraint that none of the tariffs may lie above the dumping margin. That is, for every c_d, c_f, and c,

$$m(c) \geq t(c, c), \quad m(c) \geq \tilde{t}(c, c_f|c), \quad m(c) \geq \tilde{t}(c_d, c|c).$$

As under mechanism A, the authority audits if and only if firms' reports differ. After the audit has revealed the true cost parameter c, the authority implements the constrained optimal antidumping duty $t_m^*(c)$ defined as $\min\{t^*(c), m(c)\}$, i.e., $\tilde{t}(c_d, c|c) = \tilde{t}(c, c_f|c) = t_m^*(c)$ for $c_d \neq c$ and $c_f \neq c$. If firms make identical reports $c_d = c_f$, the tariff is $t_m^*(c_d)$. All these tariffs are ex post optimal and thus credible even when they are not contractible. We call this scheme of tariffs and auditing probabilities *mechanism* B. Mechanism B and its outcome are summarized in the following proposition.

[14] In practice, it will usually be costly for the foreign firm to have such an investigation conducted. We assume that these costs are not so large that the firm refrains from defending its case.

[15] Alternatively, we could assume that the authority is obliged to conduct an audit whenever firms' reports do not coincide. Given the situation analyzed in this section, namely, a complete transparency of the antidumping investigation, compliance with such an obligation would be enforceable. However, as we will see shortly, it will be part of the authority's optimal strategy to always audit in case of diverging reports anyway.

Proposition 4.1. *If the foreign firm's marginal costs are verifiable, the following mechanism B is optimal from the authority's perspective: If $c_d = c_f$, the auditing probability is $\theta_B(c_d, c_f) = 0$ and the antidumping duty is $t_B(c_d, c_f) = t_m^*(c_d) = t_m^*(c_f)$. If $c_d \neq c_f$, $\theta_B(c_d, c_f) = 1$ and $\tilde{t}_B(c_d, c_f|c) = t_m^*(c)$.*

In equilibrium, both firms report truthfully, the authority implements $t_m^*(c)$, and an audit never takes place. Furthermore, governmental welfare is equal to $W(c, t_m^*(c))$, i.e., the maximum welfare under perfect information, given the constraint on the tariff.

Example 4.1. *In our example, the mechanism B consists of normal tariffs $t_B(c, c) = min\{(a-c)/3, m(c)\}$, punishment tariffs $\tilde{t}_B(c, \tilde{c}|c) = \tilde{t}_B(\tilde{c}, c|c) = min\{(a-c)/3, m(c)\}$ and auditing probabilities $\theta_B(c_d, c_f) = 0$ if $c_d = c_f$ and $\theta_B(c_d, c_f) = 1$ otherwise.*

5. Case 3: Tariffs at or below the maximum reported dumping margin

In this section, we consider a case that lies in-between the previous cases 1 and 2. We now assume that, as in case 1, the true cost parameter c is non-verifiable. However, contrary to case 1, the authority must not disregard firms' reports when deciding on the tariff. In particular, the authority is allowed to implement only tariffs not exceeding the maximum dumping margin reported by the two firms, i.e., the tariff must be smaller or equal $\max\{c_d - p_0, c_f - p_0, 0\}$. In actual antidumping cases, such a procedure where the assumed dumping margin is equal to $\max\{c_d - p_0, c_f - p_0, 0\}$ is also known as "adverse facts available" and has been used by U.S. antidumping authorities when the cooperation by the foreign firm has been deemed unsatisfactory. As in the foregoing sections, the authority is free to implement any arbitrary auditing procedure. This seems reasonable given the assumption that the outcome of an audit, the true cost parameter c, cannot be verified anyway.

Under these assumptions, mechanism B, which is optimal in case 2, remains feasible. When applying mechanism B, the authority induces both firms to report truthfully. Then, the maximum reported dumping margin equals the true dumping margin and the authority imposes the tariff $t_m^*(c)$. However, as we will show below, the authority might be able to do better by inducing firms to report in a way that allows to impose tariffs above the actual dumping margin $m(c)$. This is achieved by exploiting the domestic firm's interest in a high tariff to obtain maximum leeway in

setting the antidumping duty, while using the foreign firm's report to obtain truthful cost information. Note that, contrary to the previous sections, for this approach we do not have to assume that the domestic firm actually knows the foreign firm's cost parameter, since truthful cost information is provided by the foreign firm only. In the following subsection, we analyze this mechanism, denoted *mechanism C*, in detail. Afterwards, we discuss under which circumstances the authority prefers mechanism C to mechanism B.

5.1. **Truthful reporting by the foreign firm only.** Under mechanism C, the authority announces normal tariffs $t(c_f)$, punishment tariffs $\tilde{t}(c_f|c)$ as well as auditing probabilities $\theta(c_f)$ contingent on the foreign firm's report only. Consequently, the domestic firm's report affects the outcome of the antidumping investigation only through its impact on the maximum reported dumping margin. By submitting a high cost report, the domestic firm (weakly) increases the maximum reported dumping margin and, potentially, also the implemented tariff. Thus, the domestic firm reports $c_d = \bar{c}$. The maximum reported dumping margin and hence also the maximally allowed duty is thus $t_{max} = \bar{c} - p_0$. For the model to be interesting, we need that $t^*(c) < t_{max}$ for at least one of the c realizations. Otherwise it would be clear that the optimal policy is to always implement t_{max}. In the following, we restrict attention to the case $t^*(c) < t_{max}$ for *all* c.[16]

The tariffs and auditing probabilities are chosen to maximize the expectation of welfare $W(c, t(c))$ minus the expected cost of auditing

$$\alpha[W(\bar{c}, t(\bar{c})) - \theta(\bar{c})M] + (1-\alpha)[W(\underline{c}, t(\underline{c})) - \theta(\underline{c})M], \tag{5.1}$$

subject to the constraints that for all c, $\tilde{c}$ with $c \neq \tilde{c}$

$$\Pi_f(c, t(c)) \geq [1 - \theta(\tilde{c})]\Pi_f(c, t(\tilde{c})) + \theta(\tilde{c})\Pi_f(c, \tilde{t}(\tilde{c}|c)), \tag{5.2}$$

and $t_{max} \geq t(c),\ t(\tilde{c}),\ \tilde{t}(\tilde{c}|c)$.

Once again, we do not explicitly consider the foreign firm's participation constraint since it can be easily fulfilled by choosing an antidumping duty t_{max} in case the foreign firm refuses to provide a report ("adverse facts available"). Furthermore,

[16]The analysis of the general case where $t^*(c) < t_{max}$ for at least one c is very similar, except we would also have to discuss corner solutions.

in order to satisfy the foreign firm's incentive compatibility constraints (5.2), the authority cannot do better than choosing the maximum attainable tariff to punish the foreign firm in case lying has been detected, that is $\tilde{t}(c_f|c) = t_{max}$ if $c_f \neq c$ is found in an audit. To simplify notation, we define

$$\bar{t} := t(\bar{c}),\ \underline{t} := t(\underline{c}),\ \bar{\theta} := \theta(\bar{c}),\ \underline{\theta} := \theta(\underline{c}). \tag{5.3}$$

The authority's optimization problem can then be reduced to

$$\max_{\bar{t},\underline{t},\bar{\theta},\underline{\theta}} \alpha[W(\bar{c},\bar{t}) - \bar{\theta}M] + (1-\alpha)[W(\underline{c},\underline{t}) - \underline{\theta}M],$$

subject to the incentive compatibility constraints

$$\Pi_f(\bar{c},\bar{t}) \geq [1-\underline{\theta}]\Pi_f(\bar{c},\underline{t}) + \underline{\theta}\Pi_f(\bar{c},t_{max}), \tag{5.4}$$

$$\Pi_f(\underline{c},\underline{t}) \geq [1-\bar{\theta}]\Pi_f(\underline{c},\bar{t}) + \bar{\theta}\Pi_f(\underline{c},t_{max}), \tag{5.5}$$

and $t_{max} \geq \bar{t},\underline{t}$.

Intuitively, to obtain truth-telling, we need to balance lying incentives from differences in tariff rates for different cost types with differences in auditing probabilities. We will see that lower tariffs are accompanied by higher auditing probabilities and thus higher expected profit losses for an untruthful firm.

To solve the authority's problem, remember that we have assumed that $t^*(c)$ is decreasing in c, hence the authority is only interested in implementing tariff rates $t(c)$ that are also decreasing in c.[17]

From the above, we know that $\bar{t} < \underline{t} \leq t_{max}$.[18] Since the foreign firm prefers the low to the high tariff, we can immediately conclude that the high-cost type's incentive compatibility constraint (5.4) is satisfied for all auditing probabilities $\underline{\theta}$. Therefore, we can drop this constraint and set $\underline{\theta} = 0$. The simplified problem is

$$\max_{\bar{t},\underline{t},\bar{\theta}} \alpha[W(\bar{c},\bar{t}) - \bar{\theta}M] + (1-\alpha)W(\underline{c},\underline{t}), \tag{5.6}$$

[17]We prove this statement in Appendix A.

[18]The case $\bar{t} = \underline{t}$ is trivial because then the authority would not audit and always implement the tariff rate t_{ave} that maximizes $\alpha W(\bar{c},t) + (1-\alpha)W(\underline{c},t)$. This case is optimal if the functional forms are such that the implementation of tariffs marginally below and above t_{ave} increases the authority's expected auditing costs more strongly than expected welfare.

subject to

$$\Pi_f(\underline{c},\underline{t}) \geq [1-\bar{\theta}]\Pi_f(\underline{c},\bar{t}) + \bar{\theta}\Pi_f(\underline{c},t_{max}), \tag{5.7}$$

and $t_{max} \geq \underline{t}$.

For any pair of tariffs $(\bar{t},\underline{t})$, the remaining incentive compatibility constraint (5.7) must be binding. Otherwise, the authority could lower $\bar{\theta}$, thereby saving auditing costs. From the binding constraint (5.7), we obtain the optimal auditing probability for a given tariff scheme $(\bar{t},\underline{t})$,

$$\bar{\theta}(\bar{t},\underline{t}) = \frac{\Pi_f(\underline{c},\bar{t}) - \Pi_f(\underline{c},\underline{t})}{\Pi_f(\underline{c},\bar{t}) - \Pi_f(\underline{c},t_{max})}. \tag{5.8}$$

This auditing probability lies between 0 and 1 as required for a probability. It is increasing in $\underline{t}$ and decreasing in $\bar{t}$. Intuitively, the larger the difference between tariffs, the stronger is the low-cost type's incentive to lie. Stronger incentives to lie must be counteracted by a higher auditing probability.

The antidumping authority's maximization problem can now be rewritten as

$$\max_{\bar{t},\underline{t}} \alpha[W(\bar{c},\bar{t}) - \bar{\theta}(\bar{t},\underline{t})M] + (1-\alpha)W(\underline{c},\underline{t}), \quad \text{s.t. } t_{max} \geq \underline{t},$$

where $\bar{\theta}(\bar{t},\underline{t})$ is given by (5.8). For the moment, we disregard the constraint $t_{max} \geq \underline{t}$. Then, provided that the objective function is strictly concave in t, the optimal tariffs $\underline{t}_C$ and $\bar{t}_C$ are implicitly defined by the transformed first-order conditions

$$\frac{\partial W}{\partial \bar{t}}(\bar{c},\bar{t}_C) = \frac{\partial \bar{\theta}}{\partial \bar{t}}(\bar{t}_C,\underline{t}_C)M, \tag{5.9}$$

$$\frac{\partial W}{\partial \underline{t}}(\underline{c},\underline{t}_C) = \frac{\alpha}{1-\alpha}\frac{\partial \bar{\theta}}{\partial \underline{t}}(\bar{t}_C,\underline{t}_C)M. \tag{5.10}$$

We show in Appendix A that these conditions indeed characterize the optimal tariffs and, furthermore, that the tariffs lie between the perfect information tariffs, i.e., $t^*(\bar{c}) < t_C(\bar{c}) < t_C(\underline{c}) < t^*(\underline{c})$. Intuitively, the larger the gap between the low- and the high-cost tariff, $\underline{t}-\bar{t}$, the higher is the foreign firm's incentive to deliver an untruthful report if $c = \underline{c}$. To sustain truthful revelation, the authority can therefore increase $\underline{t}-\bar{t}$ only by raising the audit probability in case a high-cost report arrives. Trading off the implementation of more favorable tariffs versus expected auditing cost, the authority optimally chooses a tariff gap that is smaller than $t^*(\underline{c}) - t^*(\bar{c})$. Moreover, the implemented tariff gap decreases in auditing costs M and in the probability of a

high-cost realization, α. Intuitively, the higher the auditing cost, the more expensive it is to implement a large tariff gap. Also, the higher the probability that the foreign firm is a high-cost type, the more likely it is that a high-cost report arrives. Consequently, auditing costs have to be incurred more often, thereby making a smaller tariff gap optimal.

Proposition 5.1. *Consider the case when c is non-verifiable and tariffs must not exceed* $\max\{c_f - p_0, c_d - p_0, 0\}$. *Assume further that* $t^*(\bar{c}) < t^*(\underline{c})$. *The optimal equilibrium duties are implicitly defined by* (5.9) *and* (5.10) *and lie strictly between the full information tariffs, namely* $t^*(\bar{c}) < t_C(\bar{c}) \leq t_C(\underline{c}) < t^*(\underline{c})$. *If a high cost report arrives, the authority audits with strictly positive probability* $\theta_C(\bar{c}) = \bar{\theta}(t_C(\bar{c}), t_C(\underline{c}))$ *given by* (5.8), *and if a low cost report arrives, the authority does not audit (*$\theta_C(\underline{c}) = 0$*).*

Example 5.1. *Consider our example for the case when c is non-verifiable and tariffs must not exceed* $\max\{c_f - p_0, c_d - p_0, 0\}$. *The auditing probability when the foreign firm reports* $\bar{c}$ *equals*

$$\bar{\theta}(\bar{t}_C, \underline{t}_C) = \frac{(\underline{t}_C - \bar{t}_C)(a + k - 2\underline{c} - \bar{t}_C - \underline{t}_C)}{(t_{max} - \bar{t}_C)(a + k - 2\underline{c} - \bar{t}_C - t_{max})} \tag{5.11}$$

where $\bar{t}_C$ *and* $\underline{t}_C$ *are implicitly defined as solutions to*

$$\frac{a - \bar{c} - 3\bar{t}_C}{3} = -M\frac{(t_{max} - \underline{t}_C)(a + k - 2\underline{c} - 2\bar{t}_C)(a + k - 2\underline{c} - \underline{t}_C - t_{max})}{[(t_{max} - \bar{t}_C)(a + k - 2\underline{c} - \bar{t}_C - t_{max})]^2} \tag{5.12}$$

and

$$\frac{a - \underline{c} - 3\underline{t}_C}{3} = M\frac{\alpha}{1 - \alpha}\frac{a + k - 2\underline{c} - 2\underline{t}_C}{(t_{max} - \bar{t}_C)(a + k - 2\underline{c} - \bar{t}_C - t_{max})}. \tag{5.13}$$

For example, let $a = 100$, $\underline{c} = 10$, $\bar{c} = 50$, $k = 50$, $M = 10$, $t_{max} = 40$ *and* $\alpha = 0.1$. *The full-information tariffs are* $\bar{t}^* = 16.667$ *and* $\underline{t}^* = 30$, *whereas the optimal tariffs under mechanism C are* $\bar{t}_C = 16.870$ *and* $\underline{t}_C = 29.954$. *The corresponding optimal auditing probability in case a high-cost report arrives is* $\bar{\theta} = 0.643$.

5.2. **Comparison of the mechanisms.** We now discuss under which circumstances the authority prefers mechanism B to mechanism C in case 3. A comparison of the mechanisms is meaningful only if both firms are informed about the foreign firm's marginal cost, since only then mechanism B is feasible. The general trade-off is as

follows. Mechanism B has the advantage that the authority does not incur auditing cost. However, since both firms are made to report the foreign firm's cost truthfully, only tariffs at or below the true dumping margin can be implemented. Under mechanism C, by inducing differing reports, the authority may be able to circumvent the dumping margin constraint. However, to do so, it has to incur positive expected audit costs. To lower these costs, the authority distorts tariffs such that they always lie in-between their perfect-information counterparts.

For example, consider the case that $\underline{c} - p_0 < t^*(\bar{c}) < t^*(\underline{c}) < t_{max} = \bar{c} - p_0$. Under mechanism B, since $\underline{c} - p_0 < t^*(\underline{c})$, the implemented tariffs are $t(\underline{c}, \underline{c}) = \underline{c} - p_0$ and $t(\bar{c}, \bar{c}) = t^*(\bar{c})$. Thus, the tariff in the low-cost case is too low compared to the full-information tariff. Under mechanism C, the implemented tariff in the low-cost case is too low, whereas the tariff is too high in the high-cost case. Moreover, an audit will be conducted with strictly positive probability and hence auditing cost needs to be incurred if $c = \bar{c}$. We thus conclude that mechanism B will ceteris paribus be preferred if the auditing cost M is high. To evaluate the effect of a higher probability α of high cost, notice that under mechanism C, the probability of auditing and also the distortion of $\underline{t}_C$ compared to $t^*(\underline{c})$ are increasing in α. Moreover, under mechanism B, the probability that the right (i.e., full-information) tariff will be chosen is higher, hence the relative advantages of mechanism B are increasing in α.

6. Non-Contractible Auditing Probabilities and Tariff Schemes

In the previous sections, we assumed that auditing probabilities as well as tariff schemes contingent on firms' reports are contractible. Since these assumptions may not always be realistic, we discuss the consequences of non-contractibility in this section.

Contractibility of auditing probabilities requires that a third party be able to verify whether the authority complied with an ex-ante announced random auditing procedure. Clearly, this is difficult to accomplish in practice. Sometimes it may even be difficult to assess whether an audit has been conducted at all. For example, even if inspectors are present at the foreign firm's premises, it is hard to verify how much effort they put into the investigation. If auditing probabilities are non-verifiable,

it is impossible for the authority to commit ex-ante to an auditing procedure by contracting upon it. Moreover, any regulations provided by antidumping legislation to conduct an audit in certain cases (e.g., if firms submitted conflicting reports) are ineffective. The reason is that a third party cannot verify compliance with such a regulation. Thus, the authority can commit to an auditing procedure only if it is ex-post in its best interest to adhere to it.

Contractibility of tariff schemes appears to be easier to accomplish. In our model, it only requires that firms' reports and the subsequently implemented tariffs be verifiable, which does not seem unrealistic. However, in the real world, firms may not simply report the cost parameter but provide more diffuse information from which the antidumping authority tries to deduce the true costs. Writing a complete contract on this complex process may be impossible. Therefore, in what follows we also discuss the case of non-contractible tariffs.

6.1. **Case 1.** First consider mechanism A specified in proposition 3.1, that is optimal in case 1 if tariff and auditing schemes are contractible. As we have mentioned before, tariff credibility is not an issue under this mechanism because the tariffs both in and off the equilibrium path equal the unconstrained optimal tariffs under perfect information. Hence, they are ex post optimal and thus ex ante credible. The auditing probabilities, however, may not be self-enforcing. Mechanism A requires that the authority conduct an audit whenever diverging reports $c_d \neq c_f$ arrive. If auditing probabilities are not contractible, the threat of audit is credible if and only if the expected benefit from conducting an audit at least covers the authority's auditing costs, i.e.,

$$\alpha[W(\bar{c}, t^*(\bar{c})) - W(\bar{c}, t_{ave})] + (1-\alpha)[W(\underline{c}, t^*(\underline{c})) - W(\underline{c}, t_{ave})] \geq M, \tag{6.1}$$

where

$$t_{ave} = \underset{t}{\operatorname{argmax}}[\alpha W(\bar{c}, t) + (1-\alpha) W(\underline{c}, t)] \tag{6.2}$$

maximizes expected welfare without any further information.

Under mechanism A, the authority audits with probability one when diverging reports arrive. Clearly, there are other mechanisms with lower auditing probabilities

that also induce truthtelling and prevent auditing in equilibrium.[19] However, a lower auditing probability does not mitigate the credibility problem. The reason is that the threat of audits being self-enforcing does not depend on the ex-ante specified auditing probability. To see this, assume that, in contrast to the previous considerations, the authority announces an auditing probability $\theta(c_d, c_f) < 1$ for $c_d \neq c_f$. In this case, if firms submit differing reports, a random procedure determines whether an audit is to be conducted or not. Whenever this procedure requires an audit to occur, the authority has an incentive to audit if and only if (6.1) is satisfied.

We summarize the preceding arguments in the following proposition.

Proposition 6.1. *Consider the case when the authority can freely set the antidumping duty. The tariffs specified in proposition 3.1 are credible even if they cannot be contracted upon. Furthermore, the auditing probabilities are self-enforcing under condition* (6.1)*, i.e., provided that monitoring costs M is small compared to the welfare loss from implementing t_{ave} rather than $t^*(\bar{c})$ or $t^*(\underline{c})$.*

Intuitively, inequality (6.1) will be satisfied if implementing the average tariff t_{ave} is only a bad compromise because the optimal tariffs $t^*(\bar{c})$ and $t^*(\underline{c})$ are quite different and uncertainty about the realized cost parameter is high.

Example 6.1. *For our example with linear demand, we obtain*

$$t^*(c) = \frac{a-c}{3}, \quad t_{ave} = \frac{a - \alpha\bar{c} - (1-\alpha)\underline{c}}{3}. \tag{6.3}$$

In this case, the credibility condition can be transformed to

$$\frac{\alpha(1-\alpha)(\bar{c}-\underline{c})^2}{18} > M. \tag{6.4}$$

Thus, the threat of audit is more likely to be credible if α is close to 0.5 and $\bar{c} - \underline{c}$ is large. Then, uncertainty about the foreign firm's cost is high so that the authority strongly benefits from finding out the true cost parameter and tailoring the tariff to the actual situation. Thus, somewhat paradoxically, the authority is able to implement efficient tariffs without any audits if the quality of ex-ante information about c is poor.

[19] With lower auditing probabilities, the authority has to impose more severe punishments for a firm that has lied.

If (6.1) does not hold, firms anticipate that there will never be an audit. Consequently, under every non-constant tariff scheme, one firm always has an incentive to lie about c. The authority is therefore not able to elicit information. Consequently, there is no reason why the authority should take into account firms' reports when deciding on a tariff. After the domestic firm has filed the antidumping suit, the authority either does not ask the foreign firm for a report, or, if this is legally infeasible, disregards the information provided by the foreign firm. The authority always implements t_{ave}.

This approach can be interpreted as sticking to a "facts available" policy. Blonigen (2006) shows that this option is chosen increasingly often. Condition (6.1) suggests two possible explanations for this fact: (i) Because the number of dumping suits has increased over time, authorities may suffer from work overload so that M is high. As a consequence, they cannot credibly commit to a thorough audit. This in turn implies that it is not worthwhile to pay attention to firms' reports. Anticipating that there will be no serious audit, firms lie anyway.[20] (ii) Over time, authorities may have become more experienced, i.e., they have better estimates about foreign firms' costs, in particular if the same foreign firms are frequently the subject of dumping complaints. This would mean that t_{ave} comes relatively close to $t^*(c)$, so that the left-hand side of (6.1) decreases.

6.2. **Case 2.** In case 2, the foreign firm's marginal costs c are verifiable. As a consequence, the authority is forced to impose a tariff at or below the actual dumping margin. When analyzing case 2 in section 4, we have seen that the corresponding optimal mechanism B is quite similar to the optimal mechanism A in case 1, the only difference being that, instead of the optimal tariff scheme $t^*(c)$, now the constrained optimal tariffs $t_m^*(c)$ are implemented. Similarly to mechanism A, these tariffs are ex-post optimal and thus self-enforcing.

[20] This implies that, to implement efficient tariffs, the authority may want to have an "oversized" agency dealing with dumping suits. In equilibrium, the agency's employees would be idle, but this signals that there exist sufficient resources to conduct audits. Or, in other words, the opportunity costs of an audit are very low.

However, due to the fact that c is verifiable, mechanism B differs from mechanism A with respect to the consequences of a non-contractible auditing procedure. To see this, assume the authority does not conduct an audit when firms' reports differ. Consequently, the authority does not learn c and imposes a tariff $\hat{t}$ that will, in general, differ from $t_m^*(c)$. Then, since c can be verified in an independent investigation, there will always be a party that has an interest in requesting such an investigation. If $\hat{t} < t_m^*(c)$, the domestic firm wants to have an investigation. If $\hat{t} > t_m^*(c)$, the foreign firm asks for a review. Hence, provided that enforcing a review is not too costly for the firms, diverging reports always give rise to an investigation that reveals the true cost parameter. Anticipating these consequences, no firm has an incentive to lie given that the other firm tells the truth. Thus, even if the authority cannot commit to an audit, the verifiable nature of c sustains the truth-telling equilibrium in case 2.

Proposition 6.2. *Consider the case when c is verifiable. The tariffs specified for mechanism B in proposition 4.1 are credible even if they cannot be contracted upon. Furthermore, due to the verifiability of c, the truth-telling equilibrium can be sustained even if auditing probabilities are non-contractible.*

6.3. **Case 3.** In case 3, c cannot be verified by an independent third party. Thus, the argumentation from case 2, that firms will always enforce the tariff $t_m^*(c)$, does no longer apply under mechanism B. We therefore have to answer the question when auditing is self-enforcing under this mechanism. Under mechanism B, it is ex-post in the authority's best interest to audit if and only if

$$\alpha[W(\bar{c}, t_m^*(\bar{c})) - W(\bar{c}, \hat{t})] + (1-\alpha)[W(\underline{c}, t_m^*(\underline{c})) - W(\underline{c}, \hat{t})] \geq M, \tag{6.5}$$

where $\hat{t}$ denotes the tariff that will be implemented if firms submit diverging reports and no audit takes place. Since this tariff must not exceed the maximum reported dumping margin, we obtain $\hat{t} = \min\{t_{ave}, t_{max}\}$.

Now consider mechanism C. As we have seen in section 5, this mechanism considerably differs from mechanism B. Under the latter, auditing is supposed to occur only if firms' reports differ. An audit then indeed improves the authority's information and, consequently, may be credible. By contrast, under mechanism C, the authority must audit with positive probability even if it is clear that, due to the

incentive compatibility of the mechanism, the report is truthful. Since there is no immediate benefit from auditing, it is not self-enforcing.[21]

Furthermore, mechanism C specifies that the normal tariffs differ from the optimal perfect-information counterparts and that the punishment tariffs are maximal. This implies that neither the normal nor the punishment tariffs are credible: Once the cost report arrived, the authority would want to deviate from its announced tariff to the perfect-information tariff. Moreover, the perfect-information tariff would also be the optimal choice if ever an audit revealed that the foreign firm had lied.

Proposition 6.3. *Consider the case when c is non-verifiable and tariffs must not exceed* $\max\{c_f - p_0, c_d - p_0, 0\}$. *Assume further that contractibility of tariff schedules and auditing probabilities cannot be assumed. Under mechanism B, the tariffs specified in proposition 4.1 are self-enforcing. Furthermore, the auditing probabilities may be self-enforcing as well under condition* (6.5)*, i.e. provided that the ex-ante available information about foreign cost is poor.*

By contrast, mechanism C described in proposition 5.1 is not feasible because the authority would ex-post not want to conduct audits, and it would also want to deviate from the announced tariff schedule.

Now assume that (6.5) does not hold, implying that auditing under mechanism B is not self-enforcing. In this case, auditing might still be worthwhile for the authority if its tariff choice is not restricted by the actual dumping margin. That is, the condition

$$\begin{aligned}\alpha[W(\bar{c}, \min\{t^*(\bar{c}), t_{max}\}) - W(\bar{c}, \min\{t_{ave}, t_{max}\})] \\ + (1-\alpha)[W(\underline{c}, \min\{t^*(\underline{c}), t_{max}\}) - W(\underline{c}, \min\{t_{ave}, t_{max}\})] \geq M \quad (6.6)\end{aligned}$$

[21] Self-enforcement could be achieved in a repeated game if the authority cares about its reputation in future dumping suits (possibly involving other firms if they can observe the authority's behavior). If this is the case and the discounted expected benefit from sustaining a reputation for conducting audits exceeds M, the threat of audit is credible. However, the analysis of a repeated game structure is beyond the scope of this paper and left for future research.

may still hold. As a consequence, the authority may find it useful to employ the following *approach D*. Under this approach, the authority neither announces a tariff scheme nor auditing probabilities so that no credibility problem arises. Timing is as follows. First, the domestic firm hands in its cost report together with the antidumping suit. Afterwards, the foreign firm may hand in a report. Then, the authority decides whether to audit or not and, finally, implements a tariff at or below $\max\{c_f - p_0, c_d - p_0, 0\}$.

Given this procedure, the domestic firm will again report cost $\bar{c}$ to give the authority maximum discretion for its tariff choice. The foreign firm is indifferent between all reports and non-participation because its report does not influence the tariff choice. If the authority audits, it learns c and implements the tariff $\min\{t^*(c), t_{max}\}$. Thus, the authority audits if and only if inequality (6.6) holds.[22] Welfare is then $W(c, \min\{t^*(c), t_{max}\})$. Otherwise, there will be no audit, implying a welfare of $W(c, \min\{t_{ave}, t_{max}\})$.[23] The latter case is similar to the "facts available" policy that is applied in case 1 if auditing is not self-enforcing. The only difference is that, in case 1, the authority is not restricted in its tariff choice and can hence always implement t_{ave}.

The authority applies approach D whenever (6.5) does not hold. Moreover, even if auditing is self-enforcing under scheme B, the authority may prefer approach D. To see this, suppose condition (6.5) is satisfied. This implies that (6.6) is also satisfied and hence the authority audits under approach D. The authority then prefers approach D to mechanism B if the benefit from implementing $\min\{t^*(c), t_{max}\}$ instead of $t_m^*(c)$ outweighs the auditing costs.

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[22] Note that it is necessary for this condition to hold that $t^*(c) < t_{max}$ for at least one c. Otherwise, the left-hand side equals zero.

[23] Note that, with contractibility of tariff and auditing schemes, both the auditing and the no-auditing case are equivalent to a feasible solution to the authority's optimization problem in case 3. (The authority either announces an auditing probability of one and the implementation of $t(c_f) = \min\{t^*(c_f), t_{max}\}$, or the constant tariff $t(c_f) = \min\{t_{ave}, t_{max}\}$ and an auditing probability of zero.) However, these solutions are (weakly) dominated by mechanism C. Thus, there was no need to consider approach D before.

7. Imperfect Auditing

Thus far, we have assumed that auditing is perfect in the sense that conducting an audit always reveals the foreign firm's true marginal cost. In this section, we extend our model to a situation where auditing is imperfect, but return to the assumption that tariff and auditing schemes are contractible. We model imperfectness of the auditing procedure as follows: If a firm has lied and the authority audits, it detects lying with probability τ, where $0 < \tau < 1$. (The case $\tau = 1$ corresponds to perfect auditing. If $\tau = 0$, the authority's auditing technology is completely ineffective and it is therefore impossible to design an incentive-compatible mechanism using audits.) With probability $1 - \tau$, the authority does not uncover a wrongful report.

We first analyze the consequences of an imperfect auditing technology on the optimal mechanism in case 1, where the authority has complete freedom to set the antidumping duty. The authority, by choice of $t(c_d, c_f)$, $\tilde{t}(c_d, c_f|c)$, and $\theta(c_d, c_f)$, now maximizes

$$\alpha[W(\bar{c}, t(\bar{c}, \bar{c})) - \theta(\bar{c}, \bar{c})M] + (1 - \alpha)[W(\underline{c}, t(\underline{c}, \underline{c})) - \theta(\underline{c}, \underline{c})M],$$

subject to the constraints that, for every $c, \tilde{c} \in \{\underline{c}, \bar{c}\}$ and $\tilde{c} \neq c$, we have

$$\Pi_d(c, t(c, c)) \geq [1 - \tau\theta(\tilde{c}, c)]\Pi_d(c, t(\tilde{c}, c)) + \tau\theta(\tilde{c}, c)\Pi_d(c, \tilde{t}(\tilde{c}, c|c)) \tag{7.1}$$

and

$$\Pi_f(c, t(c, c)) \geq [1 - \tau\theta(c, \tilde{c})]\Pi_f(c, t(c, \tilde{c})) + \tau\theta(c, \tilde{c})\Pi_f(c, \tilde{t}(c, \tilde{c}|c)), \tag{7.2}$$

where participation constraints are once again omitted since they do not pose any problem (see discussion on p. 12). First note that it cannot be optimal to audit with positive probability when identical reports arrive because this would lead to positive auditing costs for the authority without helping with the incentive compatibility constraints. Hence, we must have $\theta(c, c) = 0$. However, compared to the case of perfect auditing, ensuring incentive compatibility is now more difficult. This is due to the fact that, even if the authority always audits if firms' reports are inconsistent, the lying firm remains undetected with positive probability $1 - \tau$.

Assume again that $t^*(\bar{c}) < t^*(\underline{c})$ (the opposite case can be solved analogously). We want to determine the minimum value of τ, denoted τ_{min}, for which the full-information tariffs $t^*(c)$ are still implementable. To this end, we consider the following mechanism, which is designed such that the right-hand sides of firms' incentive compatibility constraints (7.1) and (7.2) become as small as possible: The authority sets $\theta(c_d, c_f) = 1$ whenever $c_d \neq c_f$. Furthermore, it chooses $\tilde{t}(c, \tilde{c}|c) = t_0(c)$. That is, if an audit detects that the foreign firm has lied, the tariff will be such that the foreign firm leaves the market. By contrast, when an audit detects that the domestic firm has lied, the tariff will be $\tilde{t}(\tilde{c}, c|c) = 0$.

The incentive compatibility constraints can then be written as

$$\Pi_d(\bar{c}, t^*(\bar{c})) \geq [1-\tau]\Pi_d(\bar{c}, t(\underline{c}, \bar{c})) + \tau\Pi_d(\bar{c}, 0), \tag{7.3}$$

$$\Pi_d(\underline{c}, t^*(\underline{c})) \geq [1-\tau]\Pi_d(\underline{c}, t(\bar{c}, \underline{c})) + \tau\Pi_d(\underline{c}, 0), \tag{7.4}$$

$$\Pi_f(\bar{c}, t^*(\bar{c})) \geq [1-\tau]\Pi_f(\bar{c}, t(\bar{c}, \underline{c})), \tag{7.5}$$

$$\Pi_f(\underline{c}, t^*(\underline{c})) \geq [1-\tau]\Pi_f(\underline{c}, t(\underline{c}, \bar{c})), \tag{7.6}$$

where (7.3) and (7.4) are the domestic firm's incentive compatibility constraints and (7.5) and (7.6) are the foreign firm's incentive compatibility constraints.

It remains to specify the tariffs $t(\underline{c}, \bar{c})$ and $t(\bar{c}, \underline{c})$ that are implemented if $c_d \neq c_f$ and the audit delivers inconclusive results. Since the domestic firm benefits from higher tariffs and the foreign firm from lower tariffs, the domestic firm's incentive compatibility constraint (7.4) when cost is low and the foreign firm's incentive compatibility constraint (7.5) when cost is high are easily satisfied by choosing an arbitrary tariff $t(\bar{c}, \underline{c})$ from the interval $[t^*(\bar{c}), t^*(\underline{c})]$. From the other two constraints, a conflict arises: To ensure incentive compatibility for the domestic firm by condition (7.3), the tariff $t(\underline{c}, \bar{c})$ needs to be sufficiently low. By contrast, from the point of view of the foreign firm's incentive compatibility constraint (7.6), a high tariff $t(\underline{c}, \bar{c})$ is preferable. However, since $\tau > 0$, punishment tariffs are implemented with a positive probability in case a firm lies. Hence, the domestic firm's incentive compatibility constraint holds with *strict* inequality if $t(\underline{c}, \bar{c}) = t^*(\bar{c})$. Thus, to ensure truth-telling by the domestic firm, the authority can restrict attention to tariffs $t(\underline{c}, \bar{c}) > t^*(\bar{c})$. Similarly, the foreign firm's incentive compatibility constraint is satisfied with strict

inequality if $t(\underline{c},\bar{c}) = t^*(\underline{c})$. Consequently, to induce truth-telling by the foreign firm, the authority only needs to consider tariffs strictly below $t^*(\underline{c})$. We thus conclude that $t(\underline{c},\bar{c})$ can be optimally chosen from the open interval $(t^*(\bar{c}), t^*(\underline{c}))$.

To determine τ_{min}, we define the functions

$$P_d(t(\underline{c},\bar{c}),\tau) = \Pi_d(\bar{c}, t^*(\bar{c})) - [1-\tau]\Pi_d(\bar{c}, t(\underline{c},\bar{c})) - \tau\Pi_d(\bar{c},0), \tag{7.7}$$

$$P_f(t(\underline{c},\bar{c}),\tau) = \Pi_f(\underline{c}, t^*(\underline{c})) - [1-\tau]\Pi_f(\underline{c}, t(\underline{c},\bar{c})). \tag{7.8}$$

Note that both firms' incentive compatibility constraints are satisfied if and only if $P_d(t(\underline{c},\bar{c}),\tau) \geq 0$ and $P_f(t(\underline{c},\bar{c}),\tau) \geq 0$. Furthermore, P_d is decreasing in $t(\underline{c},\bar{c})$, whereas P_f is increasing in $t(\underline{c},\bar{c})$. Also, from the foregoing paragraph, $P_d(t^*(\bar{c}),\tau) > 0$ and $P_f(t^*(\underline{c}),\tau) > 0$ for all τ. All this implies that P_d and P_f can have at most one intersection in the interval $(t^*(\bar{c}), t^*(\underline{c}))$. If $P_d(t^*(\underline{c}),\tau) > P_f(t^*(\underline{c}),\tau)$, there is no intersection. Then, by choosing $t(\underline{c},\bar{c}) = t^*(\underline{c})$, the full-information tariffs can be implemented. This case occurs, if it occurs at all, if τ is sufficiently close to one. As τ decreases, P_d and P_f as functions of $t(\underline{c},\bar{c})$ shift down. At some point, we will have $P_d(t^*(\underline{c}),\tau) < 0$ and $P_f(t^*(\bar{c}),\tau) < 0$, implying that an intersection in the interval $(t^*(\bar{c}), t^*(\underline{c}))$ exists. We denote this intersection, which depends on τ, by $\hat{t}(\underline{c},\bar{c})$ and define

$$P_d(\hat{t}(\underline{c},\bar{c}),\tau) = P_f(\hat{t}(\underline{c},\bar{c}),\tau) = P(\tau). \tag{7.9}$$

Given τ, the perfect-information tariffs can be implemented if and only if $P(\tau) \geq 0$. Since P_d and P_f are increasing in τ, $P(\tau)$ is also increasing in τ. Thus, τ_{min} is given by $P(\tau_{min}) = 0$, or, equivalently,

$$\tau_{min} = \frac{\Pi_d(\bar{c},\hat{t}(\underline{c},\bar{c})) - \Pi_d(\bar{c}, t^*(\bar{c}))}{\Pi_d(\bar{c},\hat{t}(\underline{c},\bar{c})) - \Pi_d(\bar{c},0)} = \frac{\Pi_f(\underline{c},\hat{t}(\underline{c},\bar{c})) - \Pi_f(\underline{c}, t^*(\underline{c}))}{\Pi_f(\underline{c},\hat{t}(\underline{c},\bar{c}))}. \tag{7.10}$$

Example 7.1. *In our linear example, $\hat{t}$ solves*

$$\left[\frac{4a}{3} - 2k + \frac{2\bar{c}}{3}\right]^2 - (1-\tau)(a - 2k + \bar{c} + \hat{t})^2 - \tau(a + \bar{c} - 2k)^2$$
$$= \left[\frac{a}{3} + k - \frac{4\underline{c}}{3}\right]^2 - (1-\tau)(a + k - 2\underline{c} - 2\hat{t})^2 \tag{7.11}$$

and τ_{min} solves

$$\tau_{min} = 1 - \frac{(a + 3k - 4\underline{c})^2}{9[a + k - 2\underline{c} - 2\hat{t}]^2}, \tag{7.12}$$

where $\hat{t}$ *is a function of* τ_{min}*. For example, let* $a = 100$*,* $\underline{c} = 10$*,* $\bar{c} = 50$*, and* $k = 50$*. The full-information tariffs are* $\underline{t}^* = 30$ *and* $\bar{t}^* = 16.667$*. We can calculate* $\hat{t}(\underline{c}, \bar{c}) = 22.896$ *and* $\tau_{min} = 0.309$*.*

Since τ_{min} is strictly lower than one, the perfect-information tariffs may still be implementable under imperfect auditing, provided that the auditing technology is still sufficiently effective ($\tau \geq \tau_{min}$). Figure 1 in Appendix B illustrates the case where $\tau > \tau_{min}$. We see that the intersection between P_d and P_f occurs above the horizontal axis, i.e. $P(\tau) > 0$, and there exists an interval for $t(\underline{c}, \bar{c})$ for which both constraints P_d and P_f are fulfilled.

If $\tau = \tau_{min}$, the perfect-information tariffs can be implemented at the margin, i.e. it exists exactly one tariff $t(\underline{c}, \bar{c})$ which fulfils both $P_d \geq 0$ and $P_f \geq 0$, as illustrated in Figure 2 in Appendix B. The intersection between P_d and P_f occurs on the horizontal axis, i.e. $P(\tau) = 0$, and only $t(\underline{c}, \bar{c}) = \hat{t}(\underline{c}, \bar{c})$ fulfils the constraints P_d and P_f at the same time.

However, if the auditing technology is sufficiently poor ($\tau < \tau_{min}$ which can occur since $\tau_{min} > 0$), it is no longer possible to implement the perfect-information tariffs. In this case, the authority has to raise $t(\bar{c}, \bar{c})$ above $t^*(\bar{c})$ and lower $t(\underline{c}, \underline{c})$ below $t^*(\underline{c})$.

We can summarize our findings as follows:

Proposition 7.1. *Consider case 1. Suppose that* $t^*(\bar{c}) < t^*(\underline{c})$ *and auditing uncovers the foreign firm's true cost with probability* $\tau \in (0, 1)$*. If* $\tau \geq \tau_{min}$ *defined in* (7.10)*, the optimal full-information tariffs* $t^*(c)$ *can be implemented. If* τ *lies below this limit, however,* $t(\underline{c}, \underline{c})$ *has to be lowered relative to* $t^*(\underline{c})$ *and* $t(\bar{c}, \bar{c})$ *has to be increased relative to* $t^*(\bar{c})$ *to ensure incentive compatibility.*

In case 2, the analysis of the effect that imperfect auditing has on the optimal mechanism proceeds analogously to case 1. In section 4, we have shown that, under perfect auditing, the authority imposes the tariffs $t_m^*(c) := \min\{t^*(c), m(c)\}$, where $m(c)$ denotes the dumping margin. Hence, in the above analysis, we just need to replace $t^*(c)$ by $t_m^*(c)$ and require that also the tariffs that are set when the audit does not yield a result be at or below the dumping margin. We then receive a lower bound

on τ for which $t_m^*(c)$ is still implementable. If the auditing procedure becomes so imprecise that $t_m^*(c)$ is no longer feasible, the maximum and minimum implemented tariffs must be decreased and increased, respectively. In addition, increasing the implemented tariff may not be feasible due to the dumping margin constraint, in which case the other implemented tariff would need to be decreased more.

Now we turn to case 3 and suppose the authority wants to implement truthful reporting by the foreign firm only, as in mechanism C.[24] Here, we assume that, if an audit is conducted but delivers no additional information, the tariff equals the normal tariff rate $t(c_f)$. Then, imperfect auditing has a similar effect on the optimal mechanism as in the previously discussed cases. The result is stated in the following proposition.

Proposition 7.2. *In case 3, if only the foreign firm is made to report truthfully, the maximum implemented tariff increases in τ, while the minimum implemented tariff decreases.*

The proof is given in Appendix A.

8. CONCLUSION

After the completion of the GATT Tokyo Round in 1979, most-favored-nation (MFN) tariffs were further lowered (today, MFN tariff levels are quite small for most goods, at least in developed countries). At the same time, alternative trade policy instruments became more popular. The increased use of quotas and voluntary export restraints after 1979 triggered the emergence of a strategic trade policy literature that explains why authorities may want to pursue active trade policy when markets are not perfectly competitive and why the choice of trade policy instrument often matters for the policy outcome (non-equivalence of trade policy instruments). However, many trade economists lost interest in the strategic trade policy argument again, partly because the process of tariffication led to the gradual elimination of many non-tariff barriers, and partly also because strategic trade policy "presumes too much knowledge on the part of authorities" (Brander, 1995, p.1422).

[24]The analysis of the case where both firms report truthfully corresponds to case 2.

In this paper, we have argued that the dramatic increase in antidumping protection which took place after the completion of the GATT Tokyo Round, at the same time when a surge in non-tariff barriers could be observed, may actually be viewed as strategic trade policy as well. But whereas the surge in non-tariff barriers was successfully reversed (e.g., by tariffication), antidumping protection has become more and more popular, a well-established and legal measure within the framework of GATT/WTO rules to safeguard fair trade. We have shown that in theory, the antidumping procedure provides a country with the necessary means to successfully overcome the informational problems which would usually render the design of optimal strategic trade policy infeasible. Moreover, depending on the degree of freedom the antidumping authority has in choosing the antidumping duty, the authority may use the obtained information to also successfully implement the optimal full-information strategic trade policy. Thus, strategic trade policy may actually be alive and well right under the auspices of GATT/WTO.

Appendix A. Proofs

Proof that if $t^*(c)$ is decreasing, so will be $t(c)$ in case 3 (footnote 15). The proof is by contradiction. Suppose that, contrary to the claim, $t^*(c)$ is decreasing in c while $t(c)$ is increasing, i.e., $t^*(\underline{c}) > t^*(\bar{c})$ but $t(\underline{c}) < t(\bar{c})$. First, let us rule out $t(\underline{c}) < t^*(\bar{c})$. Such a tariff scheme cannot be optimal since the authority is better off by implementing $t(\underline{c}) = t(\bar{c}) = t^*(\bar{c})$ and setting $\theta(c) = 0$ for all c. Secondly, notice that $t^*(\underline{c}) < t(\bar{c})$ is not optimal, either, since the authority is better off by implementing $t(\underline{c}) = t(\bar{c}) = t^*(\underline{c})$ and setting $\theta(c) = 0$ for all c. Finally, consider $t^*(\bar{c}) \leq t(\underline{c}) < t(\bar{c}) \leq t^*(\underline{c})$. Such a scheme cannot be optimal since it is dominated by some other scheme where $t^*(\bar{c}) \leq t(\underline{c}) = t(\bar{c}) \leq t^*(\underline{c})$ and $\theta(c) = 0$ for all c. Thus, when $t^*(c)$ is decreasing in c, this must also be true for $t(c)$. □

Proof that $t^*(\bar{c}) < t_C(\bar{c}) \leq t_C(\underline{c}) < t^*(\underline{c})$ in Proposition 5.1. For the moment, we disregard the constraint $t_{max} \geq \underline{t}$. Then, provided that the authority's objective function is strictly concave, $\underline{t}_C$ and $\bar{t}_C$ are implicitly given by the first-order conditions

(5.9) and (5.10):

$$\begin{aligned}\frac{\partial W}{\partial \bar{t}}(\bar{c},\bar{t}_C) &= \frac{\partial \bar{\theta}}{\partial \bar{t}}(\bar{t}_C,\underline{t}_C)M,\\ \frac{\partial W}{\partial \underline{t}}(\underline{c},\underline{t}_C) &= \frac{\alpha}{1-\alpha}\frac{\partial \bar{\theta}}{\partial \underline{t}}(\bar{t}_C,\underline{t}_C)M.\end{aligned}$$

At the moment, we do not have an upper bound on $\underline{t}_C$ and thus only know that $\frac{\partial \bar{\theta}}{\partial \underline{t}} \geq 0$. Hence, from (5.10), we obtain $\underline{t}_C \leq t^*(\underline{c})$. However, since $t^*(\underline{c}) < t_{max}$ by assumption and therefore $\underline{t}_C < t_{max}$, it must hold that $\frac{\partial \bar{\theta}}{\partial \underline{t}}$ is strictly positive and, consequently, $\underline{t}_C < t^*(\underline{c})$. Thus, $\underline{t}_C < t_{max}$ and the disregarded constraint $t_{max} \geq \underline{t}$ is satisfied. Furthermore, since $\bar{t}_C < \underline{t}_C < t_{max}$, the derivative $\frac{\partial \bar{\theta}}{\partial \bar{t}}$ is strictly negative. Consequently, condition (5.9) implies $\bar{t}_C > t^*(\bar{c})$. □

Proof of Proposition 7.2. Let $t^*(c)$ be decreasing in c and $t^*(c) < t_{\max}$ for all c. The authority maximizes

$$\alpha[W(\bar{c},t(\bar{c})) - \theta(\bar{c})M] + (1-\alpha)[W(\underline{c},t(\underline{c})) - \theta(\underline{c})M],$$

subject to the constraints that for all c, $\tilde{c}$ with $c \neq \tilde{c}$

$$\Pi_f(c,t(c)) \geq [1-\tau\theta(\tilde{c})]\Pi_f(c,t(\tilde{c})) + \tau\theta(\tilde{c})\Pi_f(c,\tilde{t}(\tilde{c}|c)) \tag{A.1}$$

and $t_{max} \geq t(c),\ t(\tilde{c}),\ \tilde{t}(\tilde{c}|c)$. Applying the same line of argumentation as in section 5, the authority's problem can be simplified to

$$\max_{\bar{t},\underline{t}} \alpha[W(\bar{c},\bar{t}) - \bar{\theta}(\bar{t},\underline{t})M] + (1-\alpha)W(\underline{c},\underline{t}), \quad \text{s.t. } t_{max} > \underline{t},$$

where

$$\bar{\theta}(\bar{t},\underline{t}) = \frac{1}{\tau}\frac{\Pi_f(\underline{c},\bar{t}) - \Pi_f(\underline{c},\underline{t})}{\Pi_f(\underline{c},\bar{t}) - \Pi_f(\underline{c},t_{max})}. \tag{A.2}$$

From the first-order conditions, we obtain

$$\frac{\partial W}{\partial \bar{t}}(\bar{c},\bar{t}_C) = \frac{\partial \bar{\theta}}{\partial \bar{t}}(\bar{t}_C,\underline{t}_C)M, \tag{A.3}$$

$$\frac{\partial W}{\partial \underline{t}}(\underline{c},\underline{t}_C) = \frac{\alpha}{1-\alpha}\frac{\partial \bar{\theta}}{\partial \underline{t}}(\bar{t}_C,\underline{t}_C)M, \tag{A.4}$$

where $|\frac{\partial \bar{\theta}}{\partial \bar{t}}|$ and $|\frac{\partial \bar{\theta}}{\partial \underline{t}}|$ are decreasing in τ. This shows that $\bar{t}_C$ decreases in τ and $\underline{t}_C$ increases in τ. □

Appendix B. Figures

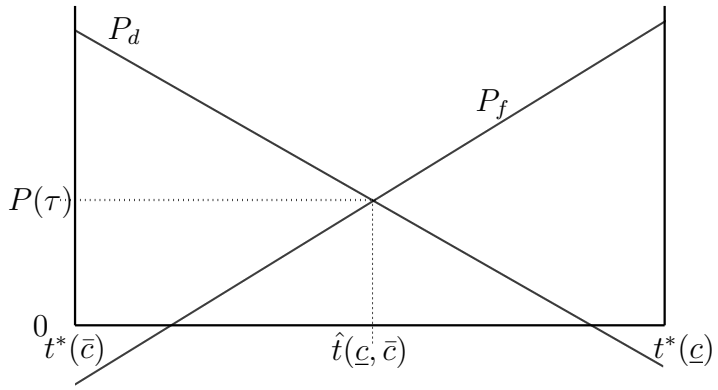

Figure 1. Both IC constraints satisfied

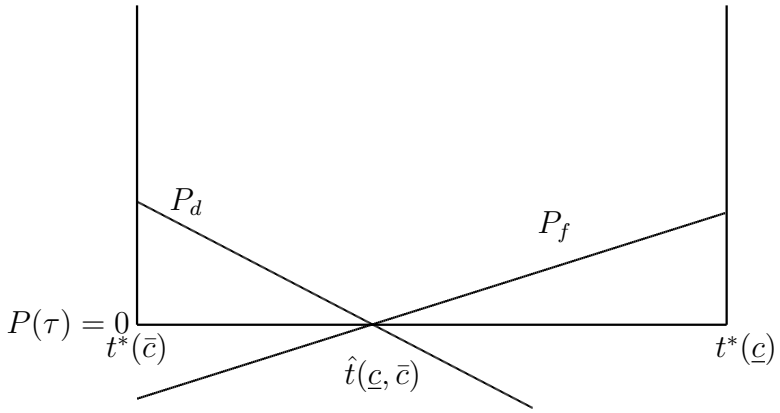

Figure 2. Both IC constraints satisfied at the margin

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