

## Price undertakings, VERs, and foreign direct investment

### The case of foreign rivalry<sup>#</sup>

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#### *Abstract*

Antidumping (AD) petitions are often withdrawn in favor of VERs and price undertakings. This paper compares the three options in the presence of protection-jumping foreign direct investment (FDI), with special emphasis on rivalry between foreign firms. We show that a VER is less likely to induce FDI than a price undertaking or AD. As a result, by settling AD cases with VER agreements, the importing country can pursue a more protectionist policy without triggering FDI. This result may explain the 1994 GATT ban on VERs following the proliferation of AD use.

**Keywords:** FDI, price undertakings, antidumping, VER, WTO

**JEL Classification code:** F1

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## 1. Introduction

Over the last-quarter century, use of antidumping (AD) has spread from a handful of users (primarily the United States and the European Union) to more than 70 countries (Prusa, 2001). In reality, however, AD petitioners often withdraw their petitions in favor of direct settlements with exporting firms or governments. For example, during the 1980-85 period over one-third of U.S. AD petitions were withdrawn in favor of VERs or voluntary export restraints (Prusa, 1992). During the same 1980-1985 period nearly half the AD petitions filed in the EU were settled through price undertakings, which are voluntary price increases offered by foreign firms to offset the injury to domestic producers due to alleged dumping (Messerlin, 1989). More recently, the U.S. and Canada have started to settle AD cases through price undertakings.<sup>1</sup>

In this paper we examine the relative effect of a price undertaking and a VER on foreign firms' incentive to engage in FDI, with special emphasis on foreign rivalry. There is a well-developed literature on "protection-jumping" FDI, but most of this literature assumes the setting in which one foreign firm competes with one home firm.<sup>2</sup> Such a framework cannot reveal any effect of rivalry between foreign firms on their incentives to engage in protection-jumping FDI.

To capture the role of rivalry in foreign firms' choice between exporting and FDI, we consider a model in which two firms from the same foreign country compete with one home firm in the home country. Our analysis offers two main results. A first is that a price

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<sup>1</sup> Use of VERs was prohibited under the GATT in 1994 (Agreement on Safeguards, Article 11) and the existing VERs have been phased out. In contrast, price undertakings remain in full compliance under GATT and WTO rules (Article 8). See Moore (2005) for more institutional backgrounds.

<sup>2</sup> See, e.g., Horstmann and Markusen (1987), Motta (1992), Ishikawa (1998), Blonigen, Tomlin and Wilson. (2004), and Belderbos, Vandenbussche, and Veugelers (2004). Miyagiwa and Ohno (1998) and Blonigen and Ohno (1998) study aspects of foreign rivalry in other contexts.

undertaking is more likely to lead to FDI than a VER. To understand this result intuitively, suppose that one foreign firm, under a price undertaking, switches from exporting to FDI while the other exports. Freed from the constraint, the investing firm expands output, depressing the price for the exporter. However, since the export price is not allowed to fall under a price undertaking, the exporter must curtail exports to keep the price up. Thus, one firm's decision to engage in FDI generates negative externalities on the exporting firm, giving each firm an incentive to invest before the rival does.

In contrast, a VER yields the opposite effect. A firm choosing FDI no longer needs its share of the export quota, so the unused portion can be reallocated to the other firm. Thus, one firm's decision to engage in FDI relaxes the quota constraint confronting the other firm. This positive externality diminishes each firm's incentive to invest before the rival. This establishes our first result.

Our second result concerns importing country welfare. Consider the case in which the home government settles an AD case through a VER or a price undertaking under the political constraint that the home firm not be made worse off as a result of the settlement. This constraint seems realistic, for otherwise the home firm would never withdraw its AD petition. In such a setting we show that home country welfare is never lower with a VER – and can be higher – than with a price undertaking. The explanation comes from our first result. Since a VER is less likely to induce FDI than a price undertaking, the home firm is less likely to be harmed when an AD case is settled with a VER agreement. This gives the home firm the opportunity to restrain more imports under a VER than under AD or a price undertaking.

That settling AD cases through VERs can spawn protectionism has an interesting policy implication. Now, since use of AD increased dramatically in the late 1980's, the 1994 GATT decision to prohibit use of VERs can be viewed as a policy against the spread of protectionism.

We now relate our work to the relevant literature. There is already a large literature on VERs. Price undertakings, too, have been receiving increasing attention from trade economists; see, for example, Vandenbussche and Wauthy (2001) and Pauwels and Springael (2002). Our study is particularly related to that of Belderbos, Vandenbussche, and Veugelers (2004). These authors consider a three-stage game, in which AD authorities first choose between an AD duty and a price undertaking, then the foreign firm chooses between exporting and FDI, and finally the foreign and the home firm compete in prices in the home market. FDI reduces the foreign firm's production cost but may not occur due to the high setup cost. In such cases, welfare-maximizing AD authorities choose an AD duty over a price undertaking to induce FDI, but if concerned with protection of the home firm, they choose a price undertaking to prevent FDI. Thus, the main focus of Belderbos et al. (2004) is on the home government's choice between an AD duty and a price undertaking, with one foreign firm, while here it is on a comparative effect of a price undertaking and a VER in the presence of rivalry between foreign firms.

Moore (2005) also examined the differences between a price undertaking and a VER, although in the absence of FDI. Assumes differentiated-goods Bertrand duopoly, he finds that a VER leads to a more collusive outcome than a price undertaking.

The remainder of the paper is organized in 6 sections. The next section outlines the model and demonstrates the equivalence among the three policy tools, AD, VERs and price

undertakings, in the absence of FDI. Sections 3, 4, and 5 then examine the effect of AD, price undertakings, and VERs, respectively, on foreign firms' incentive to engage in FDI. Section 6 discusses policy implications. Section 7 concludes.

## 2. Environment and basic results

To capture rivalry among foreign firms, the focus of our analysis, we consider a model in which two foreign firms from the same country compete with one home firm in the home market. Additional assumptions simplify the analysis and keep us focused on the main issue. Firstly, unlike in Belderbos et al. (2004) all firms are symmetric and assumed, for simplicity, to have zero production costs regardless of the location choices foreign firms make. Thus, FDI offers no advantages to foreign firms relative to exporting. However, FDI requires a fixed setup cost  $k > 0$ . Thus, foreign firms will never choose FDI over exporting under free trade. Secondly, unlike in Moore (2005) firms produce homogeneous goods and play a Cournot game. Thirdly, home market demand is linear and written

$$p = a - (x_1 + x_2 + x_h),$$

where  $a > 0$  and  $x_h$  denotes the home firm's output and  $x_1$  and  $x_2$  the two foreign firms' outputs.

Cournot competition has an advantage over Bertrand competition in that it establishes the equivalence among AD, the VER and the price undertaking, which makes it possible to isolate the effect of foreign rivalry in policy comparisons. This three-way equivalence is easy to show using Figure 1 in case of only one foreign firm.

<Please place Figure 1 around here.>

Letting  $x_h$  and  $x_f$  denote the home and the foreign firm's output, respectively, suppose that the Cournot-Nash equilibrium under free trade is indicated by point  $N$ , where the home firm's best-response function  $r_h$  intersects that of the foreign firm  $r_f$ . The imposition of AD shifts the foreign firm's best-response function to  $r_{ft}$ , and the equilibrium to  $N_t$ . Converting the AD duty to a VER has no effect on the home firm's best-response function as long as the two instruments are set initially to keep imports to the same volume. The foreign firm's best-response function consists of the vertical dashed line AB and the segment of  $r_f$  above point A. The equilibrium remains at  $N_t$ , however, proving the equivalence between the two instruments.<sup>3</sup>

Alternatively, convert the AD case to a price undertaking with the price  $\underline{p}$  that prevails at  $N_t$ . This conversion again has no effect on the home firm's best-response function, but the foreign firm's best-response function now comprises the thick line through  $N_t$ , along which the price is constant at  $\underline{p}$ , and the segment of  $r_f$  below point C. The Nash equilibrium remains at point  $N_t$ , however, thereby establishing the equivalence between AD and a price undertaking.

This result extends to the case of two foreign firms as we show in Appendix A. Thus,

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<sup>3</sup> Hwang and Mai (1988) were the first to show the equivalence between the tariff and the VER. See also Ishikawa (1994).

**Proposition 1:** In the absence of FDI, there exist a VER and a price undertaking, which are equivalent to a given AD duty.<sup>4</sup>

In Figure 1, if the foreign firm chooses FDI, the equilibrium would be at point N as under free trade. Therefore, the foreign firm's incentive to engage in FDI must be the same, whether it faces a VER or a price undertaking. This conclusion however does not extend when there are more than one foreign firm as we demonstrate in the next three sections.

### 3. Antidumping

We consider a two-stage game, in which two foreign firms simultaneously choose between exporting and FDI, and then play a quantity-setting game with a home firm in the home country.<sup>5</sup> Since profits depend on the location choice foreign firms make in the first stage, we first examine all possible second-stage games.

If both firms export under an AD duty  $t$ , each foreign firm produces  $(a - 2t)/4$  and the home firm  $(a + 2t)/4$  units at the price

$$(1) \quad p(t) = (a + 2t)/4.$$

The profit to each foreign firm is

$$(2) \quad \pi(t) = (a - 2t)^2/16,$$

and that to the home firm is

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<sup>4</sup> With Bertrand competition a VER and a price undertaking are not equivalent, as shown by Moore (2005). The non-equivalence between a tariff (or an AD duty) and a VER under Bertrand competition is due to Krishna (1989).

<sup>5</sup> Following convention, we ignore what might be going on in the foreign country market. It is straightforward to introduce the segmented foreign market, where the price is higher than in the home market, so as to motivate why there is an AD duty, to begin with.

$$(3) \quad \Pi(t) = (a + 2t)^2/16.$$

If both foreign firms invest, the AD duty no longer applies, so the equilibrium profits are  $a^2/16$  for the home firm and  $a^2/16 - k$  for the foreign firms. If only one foreign firm invests, the investor earns  $(a + t)^2/16 - k$ , while the exporter earns  $(a - 3t)^2/16$ . The following table presents the foreign firms' profits, where I denotes investing, E denotes exporting, and the first entries are the profits to the row player, the convention we retain throughout:

AD Duty (t)

	I	E
I	$a^2/16 - k, a^2/16 - k$	$(a + t)^2/16 - k, (a - 3t)^2/16$
E	$(a - 3t)^2/16, (a + t)^2/16 - k$	$(a - 2t)^2/16, (a - 2t)^2/16.$

We can now move back to the first stage of the game, in which two foreign firms simultaneously choose between I and E. We impose the following conditions on parameter values:

- (i) Simultaneous investments are profitable, or  $a^2/16 - k > 0$ ,
- (ii) AD duties are never prohibitive, or  $t < a/3$

Figure 2 presents the equilibrium outcomes for relevant values of  $k$  and  $t$  (see Lemma 1 in Appendix B for details). The figure shows, not surprisingly, that the foreign firms choose FDI over exporting when the cost of investment is relatively low and the AD duty is relatively high.

<Insert Figure 2 around here>



#### 4. Price undertakings

Suppose that (E, E) is the equilibrium outcome of the first-stage game under AD. When the AD duty is replaced by a price undertaking, we can compute the equivalent price by (1):

$$\underline{p} = (a + 2t)/4,$$

which, given that  $t < a/3$ , ranges over the interval  $(a/4, 5a/12)$ . It is convenient to consider two cases separately.

Case I:  $a/4 < \underline{p} < a/3$ .

This case corresponds to  $t \in (0, a/6)$ . If both foreign firms choose to invest, each earns  $a^2/16 - k$  as in AD cases. If both export, each earns  $\pi(\underline{p}) = \underline{p}(a - 2\underline{p})/2$  (see Appendix A). With only one firm investing, the exporter takes the home firm's and the investor's output,  $x_i$  to choose output  $x_e$  under the constraint that the price not fall below  $\underline{p}$ :

$$p = a - x_h - x_i - x_e \geq \underline{p}.$$

Calculations show that in the symmetric Nash equilibrium

$$x_e = a - 3\underline{p} < \underline{p} = x_i = x_h.$$

The investor earns

$$\pi_i(\underline{p}) = \underline{p}^2 - k,$$

while the exporter earns

$$\pi_e(\underline{p}) = \underline{p}(a - 3\underline{p}).$$

The table below summarizes the profits to the foreign firms in all second-stage games.

Price undertaking (Case I):  $a/4 < \underline{p} < a/3$

	I	E
I	$a^2/16 - k, a^2/16 - k$	$\underline{p}^2 - k, (a - 3\underline{p})\underline{p}$
E	$(a - 3\underline{p})\underline{p}, \underline{p}^2 - k$	$\underline{p}(a - 2\underline{p})/2, \underline{p}(a - 2\underline{p})/2$

Case II:  $a/3 < \underline{p} < 5a/12$

This case occurs when an AD duty was set higher, i.e.,  $a/6 < t < a/3$ . In this case,  $\underline{p}$  is so high that, when one foreign firm chooses FDI, the equilibrium price falls below  $\underline{p}$  even if the other foreign firm has no sale. That is, one firm's decision to engage in FDI forecloses the home market for the other. Thus, there is even a stronger incentive to invest than in Case I. The following table summarizes the profits in this case.

Price undertaking (Case II):  $a/3 < \underline{p} < 5a/12$

	I	E
I	$a^2/16 - k, a^2/16 - k$	$a^2/9 - k, 0$
E	$0, a^2/9 - k$	$\underline{p}(a - 2\underline{p})/2, \underline{p}(a - 2\underline{p})/2$

Figure 3 depicts the equilibrium outcomes for both cases (see Appendix B for details).

<Insert Figure 3 around here.>

A comparison with Figure 2 shows that for  $t \leq a/6$  the equilibrium (E, E) occurs in a larger set of parameter values. Intuitively, the choice between exporting and FDI depends on two effects. A first is well known; FDI is more attractive under AD than under a price undertaking because investing firms can save AD duties. A second effect is novel and is due to rivalry between foreign firms. Suppose that one foreign firm switches from exporting to FDI while the other keeps exporting. Then, industry output increases and the price falls under AD. Under a price undertaking, however, the price is not allowed to fall. So, to keep the price up the exporting firm must decrease exports even more, which benefits the investing firm. This externality makes FDI more attractive under the price undertaking.

A comparison shows that for  $t \leq a/6$  the externality effect is less important than the first effect. In contrast, for  $t > a/6$  the externality effect is dominant because of the possibility of market foreclosure to exports, so (I, I) is an equilibrium. However, when the cost of investment is sufficiently high, (E, E) can also be an equilibrium because no firm wants to invest if the rival does not. This explains the existence of multiple equilibria shown in Figure 3. We summarize the result in the next proposition.

**Proposition 2:** For  $t < a/6$ , a price undertaking induces both foreign firms to export in a broader set of parameters than the equivalent AD duty. For  $t > a/6$ , a price undertaking can induce more FDI than the equivalent AD duty.

## 5. VERs

The VER is related to the AD duty by the equivalence formula:

$$v = (a - 2t)/2,$$

which ranges over  $v \in (a/6, a/2)$  given  $t < a/3$  (see Appendix A). Under the VER agreement, total exports from the foreign country cannot exceed  $v$ ; that is,  $x_1 + x_2 \leq v$ . Assume that the foreign government initially allocates the export quota equally to both firms. If one firm chooses FDI, that firm no longer needs its quota share, so the foreign government can now allocate the entire quota  $v$  to the other foreign firm. As with a price undertaking, we consider two cases.

Case I:  $v \in (a/3, a/2)$ .

This case corresponds to  $t \in (0, a/6)$ . If both foreign firms export, each firm faces the quota  $v/2$ . Given the equivalence, the equilibrium outcome is the same as under the price undertaking. If two foreign firms invest instead, each earns  $a^2/16 - k$ . If only one firm invests, the other faces the entire quota  $v$ . In the present case, however, since the per-firm symmetric Cournot equilibrium output is  $a/4$ , the fact that  $v > a/3$  indicates that the VER is not binding. With all firms playing a Cournot game unconstrained, the equilibrium profits to the investor and the exporter, respectively, are:

$$\pi_i = a^2/16 - k, \text{ and } \pi_e = a^2/16.$$

We have obtained the following profit table.

VER (Case I):  $v \in (a/3, a/2)$

	I	E
I	$a^2/16 - k, a^2/16 - k$	$a^2/16 - k, a^2/16$
E	$a^2/16, a^2/16 - k$	$v(a - v)/2, v(a - v)/2$

We show in Appendix B that (E, E) is the only equilibrium of this game (see Lemma 4).

Case II:  $v \in (a/6, a/3]$ .

Notice that for  $v \in [a/4, a/3]$ , which corresponds to  $t \in [a/6, a/4]$ , the VER is still not binding for the exporter when the other firm chooses FDI. Therefore, (E, E) is the unique equilibrium for  $v$  in this interval. For  $v \in (a/6, a/4)$  corresponding to  $\underline{p} \in (3a/8, 5a/12)$  or  $t \in (a/4, a/3)$ , however, when one foreign firm invests, the VER becomes binding for the exporter. In equilibrium the exporter produces  $v$  units of output while the home firm and the investing firm produce

$$x_h = x_i = (a - v)/3.$$

The exporter earns  $\pi_e(v) = v(a - v)/3$ , and the investor makes  $\pi_i(v) = (a - v)^2/9 - k$ . Given the range of  $v$ , we have  $\pi_i(v) > \pi_e(v)$ , so there is now an incentive to invest if the other does not (provided that  $k$  is small). The payoffs from all the second-stage games are shown in the table below.

VER (Case II):  $v \in (a/6, a/4)$

	I	E
I	$a^2/16 - k, a^2/16 - k$	$(a - v)^2/9 - k, v(a - v)/3$
E	$v(a - v)/3, (a - v)^2/9 - k$	$v(a - v)/2, v(a - v)/2$

<Please insert Figure 4 around here>

Figure 4 depicts the equilibrium with VERs (see Lemmas 4 and 5 in Appendix B for details). A comparison of figures 2 – 4 shows that settling an AD case for a VER leads to less FDI than for a price undertaking in the sense stated in the next proposition.

**Proposition 3.** The set of parameter values in which both foreign firms choose exporting over FDI under VERs is a strict superset of those under AD and price undertakings.

The proposition implies that the home government can, for given  $k$ , choose to restrain more imports with a VER than with AD or a price undertaking without inducing protection-jumping FDI. We explore this in greater details in the next section.

## 6. Policy implications

In this section we discuss policy implications of our model. In particular, we consider the following scenario. The home firm petitions for AD protection, but is ready to withdraw the petition if a price undertaking (or VER) agreement can be worked out with the foreign firms or

the foreign government. Suppose that with AD the equilibrium outcome is  $(E, E)$ . Now, our question can be stated. Should the home government choose a price undertaking or a VER, when settling an AD case under the condition that the home firm not be hurt by the settlement? We show that the home country is generally better off with a VER than with a price undertaking. The reason is that the VER gives the home government a larger constraint set to choose a policy value from without inducing protection-jumping FDI. As a result, the government can restrain more imports, and reach a higher level of welfare, with a VER than with a price undertaking while keeping FDI out.<sup>6</sup>

Suppose that we are in Case I. If the government is constrained to stay within Case I, a price undertaking and a VER yield the same welfare level. To see this, observe that  $(E, E)$  is the equilibrium outcome under the equivalent VER whenever it is under AD. Further, in Case I a tighter VER decreases welfare (see Appendix C) while a looser VER harms the home firm. Thus, the government has no choice but to choose the equivalent VER, given the constraint that it stays in Case 1. Similarly, when settling an AD case for a price undertaking, the best the government can do is to set the equivalent price target. Thus, the price undertaking and the VER yield the same home country welfare.

Suppose next that the government can choose a protection level beyond the parameter ranges of Case I. By Proposition 3, the set of parameter values resulting in  $(E, E)$  under a VER is a strict superset of that under a price undertaking. Operating under a larger constraint set the government can do better with a VER than with a price undertaking. Thus,

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<sup>6</sup> In the present case, since there are no duties to be collected under a VER or a price undertaking, the smaller the volume of imports, the higher home welfare.

**Proposition 4.** A VER (weakly) welfare-dominates a price undertaking.

## 7. Concluding remarks

In this paper we study foreign firms' incentives to engage in FDI under a VER and a price undertaking. While there is a well-developed literature on protection-jumping FDI, our approach is novel as we focus on foreign rivalry as a determinant of FDI. Our main result is that a price undertaking gives a greater incentive to engage in FDI than a VER. The reason is that with a price undertaking one firm's decision to engage in FDI depresses the export price, forcing the exporting firm to contract exports, whereas with a VER the exporting firm can export more as an investing firm no longer uses up its share of the export quota under a VER.

We also explore policy implications of our analysis. Since a VER is less likely to induce protection-jumping FDI than AD and a price undertaking, by settling an AD case for a VER agreement the importing country government can negotiate a more protectionist outcome without harming the home firm. Thus, one interpretation of our analysis is that settling AD cases with VER agreements can lead to more trade restraint. In this respect, the GATT ban on VERs was a sensible decision to stop the spread of increases in protection.

But if GATT/WTO decisions are nothing but a reflection of member country preferences, one wonders why members agreed to the ban in the first place. To address this question, consider an extension of the present model to a symmetric two-country two-industry world, in which each country is an exporter in one industry and an importer in the other. Notice that settling an AD cases can increase the level of protection only if it raises prices. Then, social welfare, consisting of consumer surplus and all firms' profits, must decline. Therefore, even if



each country may have the incentive unilaterally to settle an AD duty for a VER, the simultaneous pursuit of such policy by both governments harms both countries. Further, a higher level of import restriction decreases total industry profit. As a result, even if they are more concerned with firm profit than consumer welfare, governments are better off agreeing to mutually ban VERs. Thus, the GATT/WTO ban on VERs can be regarded as a commitment device designed to avoid the prisoner's dilemma alluded to above.

There may be an alternative, even simpler explanation of the GATT ban on VERs in the light of our analysis. The importing country is generally worse off under a VER than under AD because there are no tariff revenues. If AD authorities could act independently to protect firms more than consumers, then it would be in the interest of the welfare-maximizing government to ban VERs. In this sense, too, the WTO ban can be regarded as a commitment device.<sup>7</sup>

Although we base our analysis on Cournot competition for simplicity's sake, the mechanism driving our results is present in Bertrand competition as well. There, with a price undertaking, investment by one firm still exerts a downward pressure on the export price, while with a VER it still relaxes the quota constraint facing the exporter. Therefore, foreign firms have more of an incentive to engage in FDI under a price undertaking than under a VER. Then our welfare implications are likely to remain valid. Further, since a VER yields a more collusive equilibrium outcome than a price undertaking as shown by Moore (2005), it makes all the more sense to ban VERs.

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<sup>7</sup> We are grateful to an anonymous referee for making suggestion that the GATT ban on VERs can be explained in the light of our model, and providing us with this particular interpretation of our result.

## Appendix A

In this appendix we prove Proposition 1 for the case of two foreign firms. Begin with a price undertaking,  $\underline{p}$ , which we assume is always binding.<sup>8</sup> Further, for any impact on imports,  $\underline{p}$  must exceed the free-trade price,  $a/4$ , which we also assume. Foreign Firm 1 maximizes profit

$$\pi_1 = (a - x_1 - x_2 - x_h)x_1,$$

subject to the constraint  $p = a - x_1 - x_2 - x_h \geq \underline{p}$ . The best-response function is

$$b_1 = \max \{a - x_2 - x_h - \underline{p}, (a - x_2 - x_h)/2\}$$

Interchanging subscripts yields the best-response function for foreign firm 2. The home firm is not constrained by the price undertaking. Solving the three-best response functions simultaneously yields the following symmetric equilibrium export sales per foreign firm

$$x(\underline{p}) = (a - 2\underline{p})/2$$

and  $x_h(\underline{p}) = \underline{p}$  for the home firm. Each foreign firm makes the profit

$$(A1) \quad \pi(\underline{p}) = \underline{p}(a - 2\underline{p})/2$$

and the home firm makes

$$(A2) \quad \Pi(\underline{p}) = \underline{p}^2.$$

We now compare an AD duty with a price undertaking that yield the same profit to the domestic firm. By comparing (3) with (A2),  $\Pi(t) = \Pi(\underline{p})$  implies:

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<sup>8</sup> For example, the European Commission closely monitors the price undertakings and imposes penalties to punish violators (Pauwels and Springael, 2002).

$$(A3) \quad \underline{p} = (a + 2t)/4.$$

A comparison with (1) shows that the price is the same with an AD duty. It is easy to check that each firm's equilibrium outputs remain identical.

Consider now a VER of size  $v$  imposed on the volume of exports from the foreign country:

$$x_1 + x_2 \leq v.$$

Assume  $v < a/2$  to have any impact on imports, and that each foreign firm exports up to  $v/2$ . It is easy to check that the Nash equilibrium is

$$(x_1, x_2, x_h) = (v/2, v/2, (a - v)/2).$$

In equilibrium, industry output is  $(a + v)/2$ , and the price is

$$(A4) \quad p = (a - v)/2;$$

The profit to each foreign firm is

$$\pi(v) = v(a - v)/2.$$

and that to the home firm is

$$(A5) \quad \Pi(v) = (a - v)^2/4.$$

We now compare a VER with a price undertaking while keeping the home firm's profit constant. By (A2) and (A5), we have

$$(A6) \quad (a - v)/2 = \underline{p}.$$

In equilibrium, each foreign firm exports  $v/2 = (a - 2\underline{p})/2$ , with the home firm producing  $(a - v)/2 = \underline{p}$ , as under the price undertaking  $\underline{p}$ . This proves the equivalence between a VER and a price undertaking.

## Appendix B

This appendix contains results we used to draw Figures 2 – 4.

### Lemma 1 With AD

A: (E, E) is the unique equilibrium if  $k > 3t(2a - t)/16$ .

B: (I, I) is the unique equilibrium if  $k < 3t(2a - 3t)/16$ .

C: Either (E, I) or (I, E) is the equilibrium if  $3t(2a - 3t)/16 < k < 3t(2a - t)/16$ .

Proof: Result A is true if both these inequalities hold:

$$(B1) \quad (a - 3t)^2/16 > a^2/16 - k,$$

$$(B2) \quad (a - 2t)^2/16 > (a + t)^2/16 - k.$$

The first is written

$$16k > 3t(2a - 3t),$$

and the second is written

$$16k > 3t(2a - t) > 3t(2a - 3t).$$

Result A is immediate. Result B holds if inequalities (B1) and (B2) hold in reverse. If (B1) holds and (B2) holds in reverse, Result C obtains.  $\square$

Lemma 2 With a price undertaking  $\underline{p} \in (a/4, a/3)$  corresponding to an AD duty  $t \in (0, a/6)$

- A. (I, I) is the unique equilibrium if  $k < t(a - 3t)/4$ .
- B. (E, E) is the unique equilibrium if  $k > t(a + 2t)/4$ .
- C. Either (E, I) or (I, E) is the equilibrium if  $t(a - 3t)/4 < k < t(a + 2t)/4$ .

Proof. Result A is true if both these inequalities hold:

$$(B3) \quad a^2/16 - k > (a - 3p)p,$$

$$(B4) \quad p^2 - k > p(a - 2p)/2.$$

Using the conversion formula, the first is written

$$16k < a^2 - (a - 6t)(a + 2t) = 4t(a - 3t)$$

and the second is written

$$16k < 4t(a + 2t).$$

Since  $4t(a - 3t) < 4t(a + 2t)$ , we obtain Result A. Result B is true if inequalities (B3) and (B4) hold in reverse. If both (B3) fails and (B4) holds, Result C obtains.  $\square$

Lemma 3: With a price undertaking  $p \in (a/3, 5a/12)$  equivalent to the AD duty  $t \in (a/6, a/3)$

- A: (I, I) is the unique equilibrium if  $k < (7a^2 + 36t^2)/144$ .
- B: The equilibrium is either (I, I) or (E, E) if  $k > (7a^2 + 36t^2)/144$ .
- C: (E, I) and (I, E) are never the equilibrium.

Proof: Result (A) is true if

$$a^2/9 - k > p(a - 2p)/2.$$

Using the conversion formula, this is written

$$k < (7a^2 + 36t^2)/144.$$

If the inequality is reversed, (E, E) is also an equilibrium. Results (C) is obvious under the assumption that  $k < a^2/16$ .  $\square$

Lemma 4: With a VER  $v \in (a/4, a/2)$  corresponding to  $t \in (0, a/4)$ , (E, E) is the unique equilibrium.

Proof. The lemma is true if

$$v(a - v)/2 > a^2/16 - k.$$

Since  $v(a - v)/2$  is bounded from below by  $a^2/9$  for  $a/2 > v > a/4$ , this inequality always holds.

$\square$

Lemma 5: With a VER  $v \in (a/6, a/4)$  equivalent to the AD duty  $t \in (a/4, a/3)$

A: (E, E) is the unique equilibrium if  $k > (44t^2 + 8at + 7a^2)/72$ .

B: (I, I) is the unique equilibrium if  $k < (16t^2 - a^2)/48$ .

C: Either (E, E) or (I, I) is the equilibrium if

$$(16t^2 - a^2)/48 < k < (44t^2 + 8at + 7a^2)/72.$$

Proof. Result A is true if both these inequalities hold:

$$v(a - v)/2 > (a - v)^2/9 - k$$

$$a^2/16 - k < v(a - v)/3.$$

Using the conversion formula, the first is written

$$k > (44t^2 + 8at - 7a^2)/72$$

and the second is written

$$k > (16 t^2 - a^2)/48.$$

Result A follows because  $(44 t^2 + 8at - 7a^2)/72 < (16 t^2 - a^2)/48$  for  $a/4 < t < a/3$ . Result B is true if both inequalities hold in reverse. Result C is true if both these inequalities hold:

$$v(a - v)/2 > (a - v)^2/9 - k$$

$$a^2/16 - k > v(a - v)/3. \quad \square$$

### Appendix C

We compute home country welfare with a price undertaking that leads to the equilibrium (E, E) in Case I. Calculations show that the equilibrium consumer surplus is  $(a - \underline{p})^2/2$ , and hence the home welfare is

$$W_{EE}(\underline{p}) = (a - \underline{p})^2/2 + \underline{p}^2,$$

where  $\underline{p} \geq a/4$ .  $W_{EE}(\underline{p})$  is decreasing for  $\underline{p} < a/3$  and increasing for  $\underline{p} > a/3$ . Welfare reaches its maximum value of  $3a^2/8$  at  $\underline{p} = a/2$ , at which imports vanish. Given the equivalence, home country welfare is also decreasing in  $t < a/6$ .

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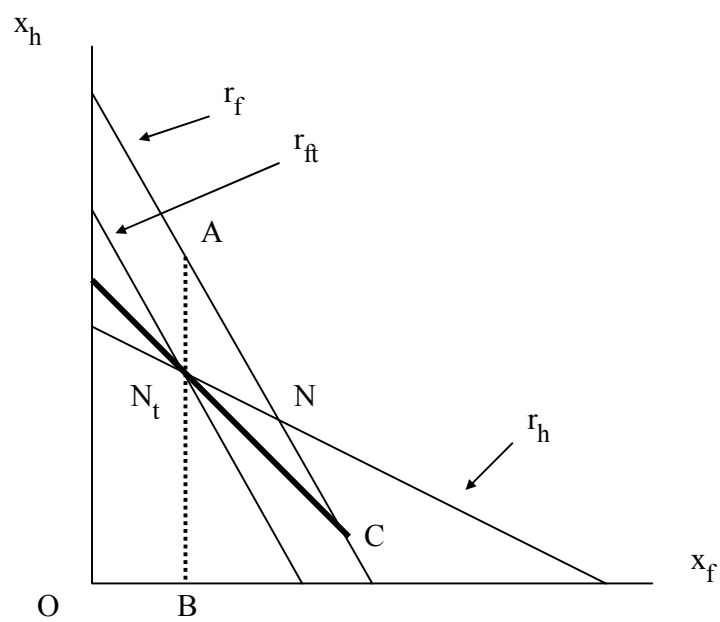


Figure 1: The equilibrium outcomes with only one foreign firm

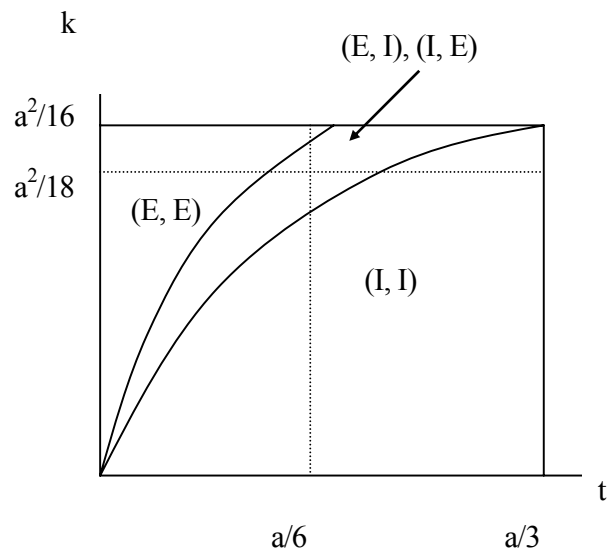


Figure 2: Equilibrium outcomes under AD

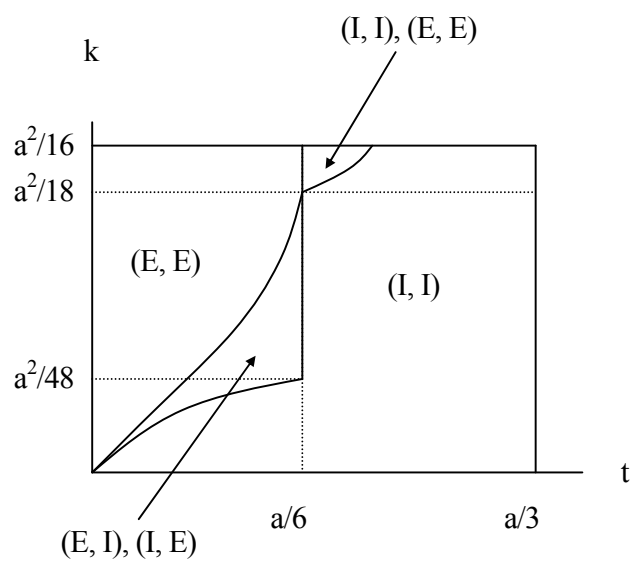


Figure 3: Equilibrium outcomes under price undertakings

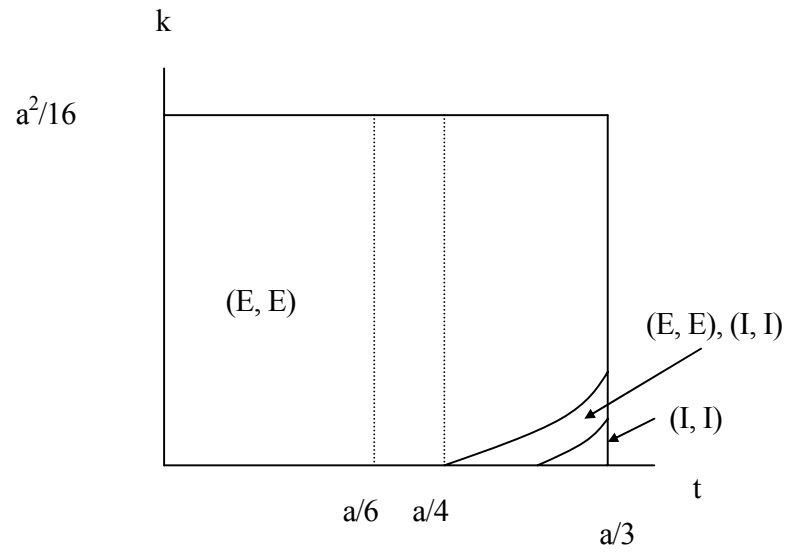


Figure 4: Equilibrium outcomes under VERs