

# Protection in Government Procurement Auctions\*

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## Abstract

Discrimination against foreign bidders in procurement auctions has typically been achieved by price preferences. We demonstrate that in the bidding game, each level of protection via a price preference can be achieved by an equivalent tariff. When government welfare depends only on net expenditures, this equivalence carries over to the government's decision. As such, this equivalence provides a justification that agreements to eliminate price preferences to be taken in tandem with agreements to lower tariffs; e.g., the Government Procurement Agreement (GPA) in the broader context of the WTO.

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# 1 Introduction

Government procurement contracts are a significant part of many economies, often amounting to 15-20 percent of GDP (WTO, 2013). When seeking a provider for a government contract, it has been a long-standing tradition that the nature of the bidding favors domestic firms over foreign ones. One common method of doing so has been the use of a price preference in which the contract is awarded to a foreign firm only if that firm's bid is sufficiently lower than the lowest bid tendered by a domestic firm. For example, under the European Community regulations, the contract was awarded to a member firm so long as its bid was no more than three percent higher than the lowest non-member bid (Branco, 1994). Across OECD countries, the estimates of Francois, Nelson, and Palmetier (1996) find that the implied margins can be as large as 30 percent. Such a preferential procurement policy can arise from a number of causes including different costs across countries (as in McAfee and McMillan, 1989) or a government which values domestic firm profits more than those of foreign firms (central to Branco's, 1994, analysis).

Obviously, price preferences are not the only policy which discriminates against foreign firms, with tariffs being but one alternative. Given the general drive towards trade liberalization, it is therefore important to understand how price preferences and tariffs compare with one another. In particular, in 1996, the Government Procurement Agreement (GPA) took steps towards non-discrimination in which signatories agree to a procurement selection process in which foreign firms are treated no differently than their domestic competitors.<sup>1</sup> As this agreement is among WTO members, understanding the substitutability between equal treatment under the bidding process and trade policy is important in understanding how the two agreements may complement each other in the broader push towards trade liberalization.<sup>2</sup>

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<sup>1</sup>See WTO (2013) for a detailed description of this agreement. For a thorough review of the successes and shortcomings of the WTO, see Bagwell et al. (2016).

<sup>2</sup>In a model of perfect competition (which is fundamentally different than the auction literature we draw from) Evenett and Hoekman (2005) compare price preferences to non-transparency, measured as a cost to foreign firms.

In this paper, we compare the use of price preferences to tariffs, establishing conditions under which the two are equivalent and when that equivalence fails, which provides insights into the ability of bans on price preferences in reducing protection against foreign firms. The environment that we consider is an auction for a government contract in which two firms, one domestic and one foreign, tender bids to the domestic government. Under a price preference, following practice, the contract is awarded to the domestic firm so long as its bid is no more than a fixed percentage higher than that of the foreign firm. In contrast, under an ad valorem tariff on a successful foreigner's bid, the contract goes to the firm with the lowest bid. Here, however, a successful foreigner must pay a tariff to the government.<sup>3</sup>

We begin by establishing an equivalence in the bidding game between the two policies, i.e., for each price preference there exists an ad valorem tariff that results in equal expected profits. In particular, under the equivalent tariff, the foreign firm scales up its bid so that it achieves the same net-of-tariff payoff if it wins the contract. We then continue by considering government welfare under the two policies in a setting where, as in Branco (1994), it may value domestic firm profits. In addition, and critically, we allow the government to value savings from a lower price differently from tariff revenues (as might be the case if tariff revenues are costly to collect). When government welfare depends simply on net revenues, i.e., tariff revenues are valued equally (but opposite) from expenditures, the same tariff equivalent to the price preference in the bidding game results in equivalent government welfare. Thus, as in Branco (1994), the optimal tariff would be positive. Further, this equivalence allows us to utilize the variety of results found in the price preference literature in a tariff setting. In addition, it suggests that in such a situation, even when price preferences are eliminated, it does not necessarily affect the equilibrium levels of protection or welfare since the government can switch to an equivalent tariff. As such movements to reduce

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<sup>3</sup>Though, in this paper, our use of a tariff is literally a discriminatory tax on the foreign firm, it need not be the case in the real world. For instance, the government could be imposing a tariff on an imported input specific to the foreign firm but which is also used throughout the domestic economy. Alternatively, the tariff could represent a profit tax on both firms, but the domestic firm is able to take advantage of a tax credit that the foreign firm can not. Thus this is discriminatory, but not overtly so. We discuss such extensions after establishing our baseline results.

protectionism are likely to be most effective when considering both tariffs and non-tariff interventions such as price preferences jointly.

That said, there are situations in which the bidders' equivalent tariff is not equivalent for the government. For example, it may be the case that tariff revenues are valued differently than expenditures. This can be the case if, as found by Riezman and Slemrod (1987), tariffs are costly to collect, implying that a dollar of gross tariff revenues are less valuable to the government than reducing expenditures by a dollar. Other examples include additional features of government welfare that depend on the tariff (such as the impact of a tariff on non-governmental consumers) or when other commitments (such as free trade agreements) constrain tariffs. In particular, if tariffs are less valued than expenditures, we find that moving from the price preference to an unconstrained tariff still works to reduce protection. Finally, note that these results are not specific to competition between domestic and foreign firms. As such, our results contribute to the more general discussion on discrimination in public procurement auctions.

The paper proceeds as follows. In Section 2, we present the model and demonstrate the equivalence of the price preference and the tariff in the bidding game. Section 3 describes government welfare and lays out conditions under which the equivalence does - and does not - extend to the government. This section also compares welfare for the various players under the two policies and compares them to the optimal price preference derived by Branco (1994). Section 4 concludes.

## 2 The Model

The model has three players: a government, a domestic firm, and a foreign firm. The government has a project of value  $V$  that it wishes to be completed. Prior to the commencement of the game, each firm  $i = d, f$  obtains a private cost  $c_i$  drawn independently from cumulative distribution  $G_i(\cdot)$  with density  $g_i(\cdot)$  on support  $[\underline{c}_i, \bar{c}_i]$ , where  $\underline{c}_i \geq 0$ . We assume that

$V > \max\{\bar{c}_d, \bar{c}_f\}$  so that in equilibrium the contract is awarded to one of the firms.<sup>4</sup> Both firms simultaneously submit bids  $b_i$  with the winner, determined by the governmental policy in place, being paid its winning bid. The mechanism for determining that winner, however, differs across policy regimes (price preference or tariff). The timing of the game is that, given its policy regime, the government chooses the extent of protection, following which bids are submitted and a winner is chosen. We assume that  $G_i$  has properties such that the equilibrium bid functions are monotone in  $c_i$  and the bid functions are continuous in the range of non-prohibitive price preferences/tariffs.<sup>5</sup> In this section, we focus on the subgame given the policy regime and the level of protection.

## 2.1 Price Preference

We begin with the price preference. Here, the domestic firm enjoys a price preference of  $p$ , where  $0 < p < 1$ , and wins as long as  $(1 - p)b_d < b_f$ , i.e., so long as its bid is no more  $1/(1 - p)$  times that of the foreign firm's bid. Note when  $(1 - p)b_d = b_f$ , the contract is randomly awarded. Also notice that this price preference is linear with respect to the bids and reflects the norm used in practice.<sup>6</sup> The linear price preference studied here is a restriction on the policy space relative to that considered by McAfee and McMillan (1989) and Branco (1994), a distinction that will be important when considering welfare in the next section.

With a price preference  $p$  in place, the expected profit for the domestic bidder is:

$$\mathbb{E}(\pi_d) = (b_d - c_d) \Pr\left(b_d < \frac{b_f}{1 - p}\right). \quad (1)$$

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<sup>4</sup>This assumption eases the presentation of the results on the optimal level of protection as the contract is always fulfilled in equilibrium. When this is not the case, it is necessary to modify the welfare function by integrating only across the cost space resulting in bids no greater than  $V$ . Further, having a  $V$  that is finite also eliminates other equilibria. See Kaplan and Wettstein (2000).

<sup>5</sup>See Reny and Zamir (2004) and Lebrun (2006) for the necessary assumptions.

<sup>6</sup>See Evenett (2002) for discussion.

Similarly, expected profit for the foreign bidder is:

$$\mathbb{E}(\pi_f) = (b_f - c_f) \Pr \left( \frac{b_f}{1-p} < b_d \right). \quad (2)$$

From the first order conditions of these equations, one obtains bid functions  $b_i(c_i; p)$ , i.e., the bid each firm would submit conditional on its own cost and the price preference. We make the standard assumption that a firm never bids below its cost even when it has a zero chance of winning.<sup>7</sup> We define inverse bid functions  $c_i(b_i; p)$ , i.e., the cost that produces a given bid conditional on the price preference.

## 2.2 Tariff

Under the tariff, the contract is awarded to whichever firm submits the lowest bid. The difference here to a standard procurement auction is that, if the foreign firm is successful, then it pays an ad valorem tariff  $t$  on its bid. In this case, domestic expected profits are (where we use tildes to denote variables and functions in the tariff regime):

$$\mathbb{E}(\tilde{\pi}_d) = (\tilde{b}_d - c_d) \Pr \left( \tilde{b}_d < \tilde{b}_f \right), \quad (3)$$

while those of the foreign firm are:

$$\mathbb{E}(\tilde{\pi}_f) = \left( (1-t)\tilde{b}_f - c_f \right) \Pr \left( \tilde{b}_f < \tilde{b}_d \right). \quad (4)$$

As with the price preference, the first order conditions for expected profits under the tariff will define bid functions  $\tilde{b}_i(c_i; t)$  which are assumed to have the same properties as the bid functions in the price preference case.<sup>8</sup> Although we focus on a tariff on the foreign firm's bid (i.e., what is directly observed by the government), we could equivalently consider

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<sup>7</sup>This assumption eliminates multiple equilibria. See Kaplan and Zamir (2015).

<sup>8</sup>In an earlier version of the paper, Cole and Davies (2014), we explicitly derive the inverse bid functions for a specific distribution of costs.

a tariff on the foreign firm's cost.

For the rest of the paper we will assume the following property.

**Property 1.** *If a bidder's cost distribution increases stochastically, so will his bid distribution.*

One interpretation of Property 1 is that as the tariff rises so too does the bid is one of tariff pass-through. Several studies find that firms facing tariffs pass on at least a portion of this to their consumers via higher prices, with Feenstra (1989) serving as the seminal work and Han, et al. (2014) and Marchand (2012) providing recent examples. Note, however, that this is not the only possibility. Studies such as Bagwell and Lee (2015) show that because overseas tariff reductions can work to lower domestic prices by driving out low-productivity firms, this can result in export prices falling as tariffs rise. Ludema and Yu (forthcoming) examine a more complex setting in which a tariff increase can also lead to lower prices as firms downgrade the quality of their product (thereby reducing the cost and the equilibrium price). Using firm level data, Ludema and Yu find evidence consistent with this possibility, particularly for low productivity firms. Such considerations, however, are entirely missing in our setting where there is only one quality, the number of firms is fixed, and non-tariff costs are exogenous to the firm.

The property should hold in almost all cases. It is proved in Lebrun (1998) for two bidders when the cost distributions have the same support.<sup>9</sup> Combining this with the continuity results in Lebrun (2002) ensures that the bid distribution will at least weakly increase even for different supports. Using the techniques in Lebrun (2006), the result should extend to a strict increase for different supports. There is not, however, a general result for more than two bidders when there are at least three different supports.<sup>10</sup> As discussed below, violations of Property 1 does not affect our equivalency results but does have implications for the optimal level of protection. We now state our first two results.

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<sup>9</sup>Lebrun (1998) also finds that the other bidder's bid distribution increases and hence the price paid would increase as well.

<sup>10</sup>A counter example is provided in Lebrun (2002).

**Lemma 1.** *For each tariff  $t$  on the foreign firm's bid, there is a tariff  $\tau = \frac{t}{1-t}$  on the cost that results in equivalent bidding behavior. When the tariff of  $\tau$  on the foreign firm's costs is combined with profit tax of  $T = t$  on the foreign firm, its expected profits are the same as the tariff of  $t$  on its bid.*

*Proof.* For the foreign firm, expected profits with a tariff of  $t$  on the bid can be rewritten as:

$$\mathbb{E}(\pi_f^{tb}) = \left( (1-t)\tilde{b}_f - c_f \right) \Pr\left(\tilde{b}_f < \tilde{b}_d\right) = (1-t) \left( \tilde{b}_f - \frac{c_f}{1-t} \right) \Pr\left(\tilde{b}_f < \tilde{b}_d\right). \quad (5)$$

This is equivalent to a tariff on costs of  $\tau = \frac{t}{1-t}$  and a profit tax of  $T = t$  on the foreign firm since we have

$$(1-t) \left( \tilde{b}_f - \frac{c_f}{1-t} \right) \Pr\left(\tilde{b}_f < \tilde{b}_d\right) = (1-T) \left( \tilde{b}_f - (1+\tau)c_f \right) \Pr\left(\tilde{b}_f < \tilde{b}_d\right). \quad (6)$$

Thus, behavior and profits will be equivalent. Since a profit tax is proportion to profits, it will not affect behavior whether or not it is imposed. When the profit tax is discriminatory and not levied on the domestic firm, the domestic firm's profits are the same regardless of whether the tariff is levied on the foreign bid or its equivalent on cost.<sup>11</sup> Again, since a profit tax is not distortionary, a non-discriminatory profit tax will not affect bidding behavior.  $\square$

**Lemma 2.** *If Property 1 holds, expected domestic profits increase in the tariff.*

*Proof.* By Property 1 an increase in a tariff on costs increases the foreign bid. This increases the probability that the domestic firm wins, increasing its expected profit even if it does not alter its bidding strategy. If it does so, this re-optimization can only further increase expected domestic profits. Since, by virtue of Lemma 1 a tariff on the bid is equivalent to a tariff on the cost, the same holds for tariffs on the bid.  $\square$

Lemma 2 highlights the role of Property 1 since, should it fail, an increase in the tariff

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<sup>11</sup>One way in which an otherwise non-discriminatory profit tax can be made discriminatory is if only the domestic firm is able to take advantage of tax offsets that are only available to those producing locally.



can lower expected domestic profits. As shown in the following, this has implications for the optimal level of protection.

## 2.3 Equivalence

We can now establish an equivalence between the tariff and price preference regimes.

**Proposition 1.** *If  $\{b_d(c_d; p), b_f(c_f; p)\}$  are equilibrium bid functions under a price premium  $p$ , then  $\{\tilde{b}_d(c_d; t), \tilde{b}_f(c_f; t)\} := \{b_d(c_d; p), (1 - p)^{-1}b_f(c_f; p)\}$  are equilibrium bid functions for a tariff  $t = p$ . Furthermore, each firm's equilibrium expected profits are equal across the two policy regimes.*

*Proof.* Since  $\tilde{b}_f(c_f; t) = b_f(c_f; p)/(1 - p)$  and  $\tilde{b}_d(c_d; t) = b_d(c_d; p)$ , expected profits for the domestic firm under the price preference can be written as

$$\mathbb{E}(\pi_d) = (b_d - c_d)Pr\left(b_d < \frac{b_f(c_f; p)}{1 - p}\right) = (\tilde{b}_d - c_d)Pr\left(\tilde{b}_d < \tilde{b}_f(c_f; t)\right) = \mathbb{E}(\tilde{\pi}_d), \quad (7)$$

which is the same as domestic firm profits under the tariff regime with  $t = p$ . As such, the bid that maximizes  $\mathbb{E}(\pi_d)$  will also maximize  $\mathbb{E}(\tilde{\pi}_d)$ . Hence, since  $\{b_d(c_d; p), b_f(c_f; p)\}$  form an equilibrium under price preferences, under tariffs given that the foreign firm bids according to  $\tilde{b}_f(c_f; t)$ , the domestic firm would choose to bid according to  $\tilde{b}_d(c_d; t)$ .

Likewise, since  $\tilde{b}_d(c_d; t) = b_d(c_d; p)$ , using a change of variables from  $b_f$  to  $(1 - p)\tilde{b}_f$ , equilibrium expected foreign profits under the price preference can be written as:

$$\mathbb{E}(\pi_f) = (b_f - c_f)Pr\left(\frac{b_f}{1 - p} < b_d(c_d; p)\right) = ((1 - p)\tilde{b}_f - c_f)Pr\left(\tilde{b}_f < \tilde{b}_d(c_d; t)\right) = \mathbb{E}(\tilde{\pi}_f). \quad (8)$$

Hence, a bid of  $b_f$  that maximizes  $\mathbb{E}(\pi_f)$  given  $b_d(c_d; p)$  will equal  $(1 - p)\tilde{b}_f$  for a bid  $\tilde{b}_f$  that maximizes  $\mathbb{E}(\tilde{\pi}_f)$  given  $\tilde{b}_d(c_d; p)$ . Therefore, when  $b_f(c_f; p)$  and  $b_d(c_d; p)$  constitute an equilibrium under a price preference  $p$ ,  $\tilde{b}_f(c_f; t) = \frac{b_f(c_f; p)}{1 - p}$  and  $\tilde{b}_d(c_d; t) = b_d(c_d; p)$  are an equilibrium under tariffs where  $t = p$ . A more general version of Proposition 1, albeit

potentially less intuitive, is presented in the Appendix. This general proof in the Appendix extends the equivalence to nonlinear policies; i.e., a tariff rate that is a function of the foreign firm's bid and the price preference rule as described in Branco (1994).  $\square$

Intuitively, when moving from the price preference  $p$  to a tariff  $t$  equal to  $p$ , the foreign firm increases its bid so that its after-tariff payment is the same. Since this does not alter the probability of one firm winning over another, it does not change behavior by the domestic firm. Together these imply that equilibrium expected profits are the same.

## 2.4 The Government

In this subsection we establish conditions under which the two policies are also equivalent for the government. In both regimes, the government sets the relevant tariff to maximize its expected welfare function, which is the sum of the value of the project, the expected payoff conditional on the domestic firm winning, and the expected payoff conditional on the foreign firm winning. In this, the government weights the domestic firm's profits by  $\theta \in [0, 1]$ . Such weighting is comparable to McAfee and McMillan (1989). If  $\theta = 0$ , the profit of the domestic firm has no effect on the government's welfare function and if  $\theta = 1$ , the domestic firm's profit fully enters the government's welfare function (as it does in Branco, 1994). In addition, in the tariff regime, tariffs are weighted by  $\rho > 0$ . If  $\rho = 1$ , then welfare depends on net expenditures (i.e., the bid paid net of tariff revenues collected). If  $\rho < 1$ , this can represent a situation in which revenues are costly to collect. Evidence of such costly administration is provided in Riezman and Slemrod (1987).<sup>12</sup> Alternatively, if  $\rho > 1$  this can represent the interests of a Leviathan government which values incoming funds that it can appropriate for itself.<sup>13</sup>

Denote  $c_d(b; p)$ ,  $c_f(b; p)$ ,  $\tilde{c}_d(b; p)$ ,  $\tilde{c}_f(b; p)$  as the respective inverse bid functions for the

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<sup>12</sup>In this vein, it is natural to assume that for a negative tariff (i.e., a subsidy) that there is a similar cost to providing the subsidy, making  $\rho \geq 1$  for such cases. This assumption prevents a scenario in which the government's cost is less than the subsidy. To streamline presentation, we focus on non-negative tariffs and raise this issue only when necessary.

<sup>13</sup>See Padovano (2004) for a review of the Leviathan literature.

domestic and foreign firms under price preferences and tariffs. The conditional on a cost  $\hat{c}_d$  for the domestic firm, conditional expected welfare under the price preference is:

$$\begin{aligned}
W(\hat{c}_d, p) = & V - \int_{c_f}^{c_f((1-p)b_d(\hat{c}_d;p);p)} b_f(c_f; p) g_f(c_f) dc_f \\
& - \int_{c_f((1-p)b_d(\hat{c}_d;p);p)}^{\bar{c}_f} [b_d(\hat{c}_d; p) - \theta (b_d(\hat{c}_d; p) - \hat{c}_d)] g_f(c_f) dc_f
\end{aligned} \tag{10}$$

and expected welfare is:

$$W(p) = \int_{c_d}^{\bar{c}_d} W(\hat{c}_d, p) g_d(\hat{c}_d) d\hat{c}_d. \tag{11}$$

Likewise, under the tariff, expected welfare is:

$$\tilde{W}(t) = \int_{c_d}^{\bar{c}_d} \tilde{W}(\hat{c}_d, t) g_d(\hat{c}_d) d\hat{c}_d. \tag{12}$$

where

$$\begin{aligned}
\tilde{W}(\hat{c}_d, t) = & V - \int_{c_f}^{\tilde{c}_f(\tilde{b}_d(\hat{c}_d;t);t)} [(1 - \rho t) \tilde{b}_f(c_f; t)] g_f(c_f) dc_f \\
& - \int_{\tilde{c}_f(\tilde{b}_d(\hat{c}_d;t);t)}^{\bar{c}_f} [\tilde{b}_d(\hat{c}_d; t) - \theta (\tilde{b}_d(\hat{c}_d; t) - \hat{c}_d)] g_f(c_f) dc_f.
\end{aligned} \tag{13}$$

The above builds the framework for our second proposition.

**Proposition 2.** *When  $\rho = 1$ , the price preference and tariff regimes are equivalent for government welfare whenever  $p = t$ .*

*Proof.* From Proposition 1, we have that inverse bid functions are such that  $\tilde{c}_f(\tilde{b}_d(\hat{c}_d; p); p) = c_f((1-p)b_d(\hat{c}_d; p); p)$ , meaning that when  $t = p$ , the probability of winning under either regime for a foreign firm with a given cost is the same. With this in mind and using Proposition 1's results for the bidding functions, welfare under the price preference, equation (10),

can be rewritten as:

$$\begin{aligned}
W(\hat{c}_d, p) = & V - \int_{c_f}^{\tilde{c}_f(\bar{b}_d(\hat{c}_d; p); p)} (1-p)\tilde{b}_f(c_f; p)g_f(c_f)dc_f \\
& + \int_{\tilde{c}_f(\bar{b}_d(\hat{c}_d; p); p)}^{\bar{c}_f} \left(-\tilde{b}_d(\hat{c}_d; p) + \theta\tilde{\pi}_d(\hat{c}_d; p)\right)g_f(c_f)dc_f.
\end{aligned} \tag{14}$$

As such, when  $p = t$  and  $\rho = 1$ , we find that:

$$W(\hat{c}_d, p) = \tilde{W}(\hat{c}_d, p). \tag{15}$$

Integrating across the potential domestic costs, we see that the equivalence therefore extends to the government when  $\rho = 1$ . □

Intuitively, moving from a price preference to the equivalent tariff results in no change for the domestic firm bid and the foreign firm increasing its bid by the amount of the tariff it would pay. When  $\rho = 1$  and the government values a dollar saved from a lower bid the same as a dollar gained from a higher tariff, the higher bid paid to a winning foreigner is exactly offset by the tariff revenue, making it indifferent between the policy regimes whenever  $p = t$ . As with the equivalency for firms, this does not rely on Property 1.

### 3 The Equilibrium Level of Protection

In the previous section, we showed that for firms, for each price preference there is an equivalent tariff and vice versa with this equivalence extending to the government whenever its objective depends solely on net expenditures. In this section, we discuss the government's optimal level of protection under each policy regime. For the moment, we focus on the case where  $\rho = 1$  so that the equivalence extends to the government. The advantage of doing so is that it allows us to more easily compare our results to the existing literature on price preferences to identify when the optimal tariff is positive.

In the literature, two situations are often offered for why foreign firms may be discriminated against. The first is when domestic profits are valued. Examples here include Branco (1994) and McAfee and McMillan (1989). The second is when foreign firms have an expected cost advantage as in McAfee and McMillan (1989) (which is an extension of the classic result of Myerson, 1981).<sup>14</sup> Note that the above equivalence result encompasses both cases. Nevertheless, this does not immediately imply that a price preference or tariff will be used because those studies consider optimal policies under either direct mechanisms (Branco, 1994 and McAfee and McMillan, 1989) or when price preferences can be non-linear in a first-price auction (Branco, 1994 and McAfee and McMillan, 1985). As derived in those papers, the optimal price preference is indeed non-linear in the foreign bid. Our analysis, however, restricts itself to the types of policies actually observed, i.e., linear price preferences and ad valorem tariffs. We can, however, state the following two results.

**Lemma 3.** *The government's preferred linear price preference (and equivalent tariff if  $\rho = 1$ ) cannot result in strictly higher welfare than its preferred price preference when non-linear price preferences are permitted.*

*Proof.* Since the set of linear price preferences is a subset of the price preference space that includes non-linear ones, the optimum from this set cannot do better for the home government. Furthermore if the preferred price preference is non-linear, as in the cases considered by Branco (1994) and McAfee and McMillan (1989), the government's equilibrium welfare under its preferred linear price preference must be lower than the one achieved under these alternative policies.<sup>15</sup> □

**Proposition 3.** *If cost distributions are the same between the domestic and foreign firms, then whenever domestic profits are valued, the government's preferred price preference and its preferred tariff are strictly positive for  $\rho$  close to 1.*

<sup>14</sup>See Jahiel and Lamy (2015) for a recent discussion on the generality of this result.

<sup>15</sup>Cole and Davies (2014) provide a numeric comparison under the preferred tariff (when  $\rho = 1$ ) and the optimal non-linear preference derived by Branco (1994) for a first-price auction. Fronk (2015) solves for the optimal price preference in a setting where costs are Pareto distributed and finds that the optimal price preference is in fact a linear one.

*Proof.* Rewrite (12) as:

$$\tilde{W}(t) = V - \mathbb{E}[\tilde{b}^*(t)] + \rho \mathbb{E}[TR(t)] + \theta \mathbb{E}[\tilde{\pi}_d(t)]. \quad (16)$$

Written this way, welfare is the value of the project minus the expected winning bid plus the expected benefits from tariff revenues and the value of the expected profits of the domestic firm. Taking the derivative of  $\tilde{W}(t)$  with respect to the tariff yields:

$$\frac{d\tilde{W}(t)}{dt} = -\frac{d\mathbb{E}[\tilde{b}^*(t)]}{dt} + \rho \frac{d\mathbb{E}[TR(t)]}{dt} + \theta \frac{d\mathbb{E}[\tilde{\pi}_d(t)]}{dt}. \quad (17)$$

Rearranging by adding and subtracting  $\frac{d\mathbb{E}[TR(t)]}{dt}$  yields:

$$\frac{d\tilde{W}(t)}{dt} = \underbrace{\frac{d\mathbb{E}[TR(t)]}{dt} - \frac{d\mathbb{E}[\tilde{b}^*(t)]}{dt}}_{\text{underbraced term}} + (\rho - 1) \frac{d\mathbb{E}[TR(t)]}{dt} + \theta \frac{d\mathbb{E}[\tilde{\pi}_d(t)]}{dt}. \quad (18)$$

From Proposition 2, the underbraced term is equivalent to  $\frac{dW(p)}{dp}$  when  $\theta = 0$ , which we will define to be  $\frac{d\tilde{W}(p)}{dp}$ .

As has been established in papers such as McAfee and McMillan (1989), when there are cost distribution asymmetries which favor the foreign firm it is beneficial to use a non-linear protection.<sup>16</sup> If, on the other hand, the cost distributions are identical, the expected payment is minimized under free trade as this results in identical bid functions, ensuring that the lowest-cost firm wins the contract (which is the optimal mechanism if the government is constrained to always make a purchase when value is above costs). Thus, at  $t = 0$ , with equal cost distributions,  $\tilde{c}_f(\tilde{b}_d(\hat{c}_d; 0); 0) = \hat{c}_d$ , we have  $\left. \frac{d\tilde{W}(p)}{dp} \right|_{t=p=0} = 0$ . (Note the optimality of setting  $p = 0$  is not a corner solution since  $p < 0$  is also inferior to  $p = 0$ .) From equation

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<sup>16</sup>Or, more generally, to discriminate against the firm with the cost advantage.

(18), at equal cost distributions we then have:<sup>17</sup>

$$\left. \frac{d\tilde{W}(t)}{dt} \right|_{t=0} = (\rho - 1) \mathbb{E}[\tilde{b}_f(c_f, t)] \Big|_{t=0} + \theta \left. \frac{d\mathbb{E}[\tilde{\pi}_d(t)]}{dt} \right|_{t=0}. \quad (19)$$

The first term is negative for any  $\rho < 1$ . By Lemma 1 the second term is positive when  $\theta > 0$ . Thus, when cost distributions are identical and  $\rho$  is sufficiently close to one, a positive tariff will be used when  $\theta > 0$ . Similarly, since first order condition under the price premium regime would be obtained by setting  $\rho = 1$  in (19), when cost distributions are identical a positive price preference will be used when domestic profits are valued.  $\square$

Thus, when cost distributions are the same, protection will be used so long as domestic profits are valued and  $\rho$  is sufficiently large.<sup>18</sup> Although we do not rely on a specific cost distribution for this result, it has been demonstrated by Cole and Davies (2014) using Kaplan and Zamir's (2012) results for uniformly distributed costs and a tariff and by Hubbard and Paarsch (2009) who simulate bid functions under a variety of cost distributions with a price preference. Again, when  $\rho = 1$  it is possible to extend their findings from one policy to another.

When cost distributions differ, as in McAfee and McMillan (1989), there is an advantage to discriminating against the firm with the advantageous cost. In that case, the result depends on the rate at which the bid functions move under the relevant ranges of the foreign cost. As initially shown by Myerson (1981) and expanded on by others including McAfee and McMillan (1989) (who expand the number of bidders), the government's expected payment can be lowered by introducing a non-linear price preference against the firm with an expected cost advantage. When using a linear price preference, the simulations provided by McAfee and McMillan (1989) show that there is still an advantage to protection (albeit a smaller

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<sup>17</sup>Note that  $\left. \frac{d\mathbb{E}[TR(t)]}{dt} \right|_{t=0} = \mathbb{E}[\tilde{b}_f(c_f, t)] \Big|_{t=0}$ .

<sup>18</sup>Note that our assumption that  $\rho \geq 1$  when  $t < 0$  rules out a subsidy as the optimal policy. However, if Property 1 fails, expected domestic profits decrease in the tariff and a subsidy can become optimal unless  $\rho$  is sufficiently larger than 1.

one as per Lemma 3) and that the losses from using a linear rather than the optimal price preference are small. Using the equivalence result, this indicates that a positive tariff would be used in such a case as well. Furthermore, as their simulations do not include domestic profits in the government welfare function, adding that would give the government further reason to use protection. In particular, this latter effect can give rise to protection even when the domestic firm(s) have cost advantages. Thus, our equivalence result allows us to extend the equilibrium use of tariffs into the variety of settings already considered by those using price preferences which show that in a variety of settings protection will be used to increase government welfare.<sup>19</sup> As a final point, recognize Myerson (1981) and McAfee and McMillan (1989) are based on particular assumptions under which Property 1 holds. Nevertheless, our equivalency result does not hinge upon this. As such, any results on the optimal price preference would carry over to the optimal equivalent tariff.

In addition to showing that protection will be used, we can identify conditions for which the equilibrium level of protection is increasing in the weight placed on domestic profits.

**Proposition 4.** *The government's preferred level of protection is increasing in  $\theta$ .*

*Proof.* Note from Equation (17), the first derivative of  $\tilde{W}$  is increasing in  $\theta$ . Let us add  $\theta$  as a parameter to welfare by denoting welfare as  $\tilde{W}(t, \theta)$ . Denote  $t_1$  as the optimal tariff level for  $\theta_1$ . Optimality of  $t_1$  means that  $\tilde{W}(t_1, \theta_1) \geq \tilde{W}(t_2, \theta_1)$  for all  $t_2$  including  $t_2 \leq t_1$ . Since  $\tilde{W}(t_1, \theta_1) = \tilde{W}(t_2, \theta_1) + \int_{t_2}^{t_1} \frac{d\tilde{W}(\tilde{t}, \theta_1)}{d\tilde{t}} d\tilde{t}$ , we have  $\int_{t_2}^{t_1} \frac{d\tilde{W}(\tilde{t}, \theta_1)}{d\tilde{t}} d\tilde{t} \geq 0$ . Thus, for  $\theta_3 > \theta_1$ , we have  $\int_{t_2}^{t_1} \frac{d\tilde{W}(\tilde{t}, \theta_3)}{d\tilde{t}} d\tilde{t} \geq 0$ . Hence,  $\tilde{W}(t_1, \theta_3) \geq \tilde{W}(t_2, \theta_3)$  for all  $t_2 \leq t_1$ . Finally, if  $t_1 > 0$  and  $\frac{d\mathbb{E}[\tilde{\pi}_d(t)]}{dt} > 0$ , then we have  $\frac{d\tilde{W}(t_1, \theta_3)}{dt} > 0$  and there exists a  $t > t_1$  such that  $\tilde{W}(t, \theta_3) > \tilde{W}(t_1, \theta_3)$  – the optimal must be strictly higher than  $t_1$ .  $\square$

Note that this depends in an obvious way on Lemma 2; if domestic profits fall in protection then the optimal level of protection declines in  $\theta$ . Finally, note that this protection is optimal from the perspective of the government. Defining global welfare as the sum of  $W$  and

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<sup>19</sup>It should be noted, however, that the simulations of Deltas and Evenett (1997) find that such gains are likely to be modest.



expected profits, the global welfare maximizing level of protection will generally differ. In one particular case, the solution to global welfare maximization is simple.

**Proposition 5.** *When  $\theta = 0$  and cost distributions are identical, the globally desired price preference is zero. If  $\rho \leq 1$ , the global welfare maximizing tariff is zero.*

*Proof.* When  $\theta = 0$ , welfare under the price preference is  $V$  minus the expected production cost of the winner. Thus, it is advantageous from a global perspective to award the contract to the lowest cost firm which happens when there is no price preference. Further, when  $\rho \leq 1$  and any tariff revenue enters global welfare negatively, no tariff will be used.  $\square$

Note the importance of the welfare weights in this result. If  $\theta > 0$  there is a “double counting” of domestic profits that gives an incentive to protect the domestic firm on a global as well as national level. Similarly if  $\rho > 1$ , there is a double counting of tariff revenues (as might occur if such revenues are being used to fund a publicly-provided good). Conversely, if  $\rho < 1$ , then a corner solution would be reached in the optimal tariff (i.e., the globally optimal tariff would be zero). These double-counting issues must therefore be kept in mind when discussing global welfare. Note that as bids cancel out in this calculation, it is independent of Property 1.

### 3.1 Non-equivalence

In the above discussion we focused on the case where policy equivalence holds not only for firms, but for the government as well. This latter condition requires two things:  $\rho = 1$  and feasibility of the equivalent tariff. As noted above,  $\rho$  need not equal 1 since tariff revenue may be less valued (such as when there is a cost to collecting revenues) or more valued (as in the case of corruption) than payments. This then begs the question of how the optimal tariff, and thus the optimal level of protection, varies in  $\rho$ .

**Proposition 6.** *If expected tariff revenues are increasing (decreasing) in the tariff at a tariff equal to the preferred price preference, then:*

1. *The optimal tariff is rising (falling) in  $\rho$ .*
2. *When  $\rho < 1$ , the equilibrium tariff is less (more) protectionist than the equilibrium price preference and the government prefers the price preference over the tariff.*
3. *When  $\rho > 1$  the equilibrium tariff is more (less) protectionist and the government prefers the tariff.*

*Proof.* As discussed above, the equilibrium price preference will equal the tariff that sets (17) equal to zero when  $\rho = 1$ .<sup>20</sup> Denote this price preference  $\tilde{p}$ . Using this in (17) but not setting  $\rho = 1$ , at a tariff of  $\tilde{p}$ , the government's first order condition can be written as:

$$\left. \frac{d\tilde{W}(\hat{c}_d, t)}{dt} \right|_{t=\tilde{p}} = (\rho - 1) \left. \frac{d\mathbb{E}[TR(t)]}{dt} \right|_{t=\tilde{p}}. \quad (20)$$

Thus, if tariff revenues are increasing in the tariff at  $t = \tilde{p}$ , then the government sets  $t < \tilde{p}$  if  $\rho < 1$ . At this tariff, welfare is lower than by  $1 - \rho$  times the tariff revenues as compared to welfare under a price preference equal to the equilibrium tariff. Since that price preference could have been chosen but was not, this means that welfare under the tariff is lower than under the price preference. If, on the other hand  $\rho > 1$ ,  $t > \tilde{p}$ . Since welfare is higher under a tariff of  $\tilde{p}$  by  $\rho - 1$  times tariff revenues, government welfare is higher under the tariff and rises by even more as it reoptimizes. If tariff revenues are declining in the tariff, then the comparisons of the equilibrium tariffs and price preferences reverse themselves. Nevertheless, the government continues to prefer the price preference when  $\rho < 1$  and the tariff when  $\rho > 1$ . □

Thus if tariff revenues are increasing in the tariff, then whenever the government prefers saving on the price it pays relative to an equivalent amount of tariff revenues, then moving from the price preference to the tariff will lower protection. Further, despite this perception by the government, if global welfare is based on equal valuations (as in Proposition 5), then

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<sup>20</sup>Note that this is true even when cost distributions differ.

moving from the price preference to a tariff increases welfare. On the other hand, if  $\rho > 1$  the reverse happens. As such, values of  $\rho \neq 1$  result in non-equivalence.

A key aspect of this is that it hinges on whether tariff revenues are increasing or decreasing at the tariff equal to the equilibrium price preference. If the only incentive for using tariffs is to maximize tariff revenues, this would exactly cancel out. In the current setting, however, two other factors influence the desired degree of protection. First, whenever  $\theta > 0$  and the government values additional profits, it has an incentive to increase the tariff in order to benefit the domestic firm. If this is large relative to other considerations, it may therefore be willing to set a level of protection above the tariff revenue maximizing choices. Second, there is the desire to manipulate bid functions and the expected payment. The direction and size of this depends on cost structures and especially the differences between them.

A second circumstance that can result in non-equivalence, even if  $\rho = 1$ , is when there are additional factors feeding into the tariff choice. One such situation would be where a tariff affects the pricing of the foreign firm beyond its transaction with the government, i.e., there is private as well as public consumption. As discussed by Miyagawa (1991), when public and private consumption are linked, this affects the optimal level of protection in the presence of non-constant marginal costs. As the price preference is perhaps more “targetable” than tariffs as it only applies to government transactions, it may be preferable as in certain situations it can be less distortive of consumer behavior. A second situation is where the choice of tariff is limited by, for example, trade agreements. Clearly, regardless of the level of  $\rho$ , if the government’s preferred tariff exceeds what it can set under the trade agreement, then equivalence will break down. In particular, if  $\rho = 1$  and there is a binding limit on the government’s preferred tariff, then eliminating price preferences will result in lower (if still positive) protection, increasing global welfare when there are equal weights.

### 3.2 Domestic Content Contingent Policies

In the above, we assumed that the tariff could not be avoided via the use of domestic content (which would not cross a border and would therefore be untaxed). Likewise, we assumed that the price preference was independent of the extent to which the foreign firm uses domestic inputs. Nevertheless, many price preferences are contingent on domestic content. For example, the Buy American Act (41 U.S.C. §8301-§8305) waives the price preferences when at least 50% of inputs are obtained within the US.<sup>21</sup> Here, we show that there again exist an equivalence between domestic content contingent tariffs and price preferences.

To see this modify the above model so that the price preference  $p(d)$  is a decreasing function of the percentage of domestic content  $d \in [0, 1]$ , where the cost for a firm with baseline cost  $c_f$  (which is randomly distributed as before) with domestic content share  $d$  is  $\delta(d; c_f)$  and  $\delta(0; c_f) = c_f$ . Firms take the price preference (or tariff) schedule as given and privately observe their costs. We assume  $\delta_d(d; c_f) \geq 0$  and that  $\delta_d(1; c_f)$  is sufficiently large so that  $d \in (0, 1)$  when there is a positive tariff or price preference. If the price preference is a step function such as that used by the US where there is no discrimination for any  $d \geq 0.5$ , this would mean that the foreign firm uses either  $d = 0$  or  $d = 0.5$ , depending on which yields higher profits. Further, if  $\delta_{d,c_f}(d, c_f) > 0$  the US policy would imply lower cost foreign firms would be those that would tend to use domestic content. This is intended to capture the added costs to the foreign firm when sourcing a share  $d$  of its requirements  $c_f$  in the contracting country. The firm then privately submits its bid along with its domestic content usage,  $d$ . We assume the domestic firm uses only domestic content. While the domestic bidder's expected profits remain:

$$\mathbb{E}(\pi_d) = (b_d - c_d) \Pr \left( b_d < \frac{b_f}{1 - p(d)} \right). \quad (21)$$

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<sup>21</sup>See Manuel (2016) for discussion.

those of the foreign bidder are now:

$$\mathbb{E}(\pi_f) = (b_f - \delta(d; c_f)) \Pr \left( \frac{b_f}{1 - p(d)} < b_d \right). \quad (22)$$

Similarly, let the tariff on the foreign firm's bid also be a function of the endogenously chosen domestic content  $t(1 - d)$ , where  $1 - d$  is the percentage of imported content.<sup>22</sup> We then have:

$$\mathbb{E}(\tilde{\pi}_d) = (\tilde{b}_d - c_d) \Pr \left( \tilde{b}_d < \tilde{b}_f \right), \quad (23)$$

while those of the foreign firm are:

$$\mathbb{E}(\tilde{\pi}_f) = \left( [1 - t(1 - d)]\tilde{b}_f - \delta(d; c_f) \right) \Pr \left( \tilde{b}_f < \tilde{b}_d \right). \quad (24)$$

As in Proposition 1, when  $\{b_d(c_f; p(d)), b_f(c_f; p(d), d(c_f))\}$  is the equilibrium under the domestic-content contingent price preference policy, then

$$\left\{ \tilde{b}_d(c_f; t(1 - d)), \tilde{b}_f(c_f; t(1 - d), d(c_f)) \right\} := \left\{ b_d(c_f; p(d)), (1 - p(d))^{-1} b_f(c_f; p(d), d(c_f)) \right\}$$

will be an equilibrium when  $p(d) = t(1 - d)$ . To see this, note that expected profits for the domestic firm under the price preference can be written as

$$\begin{aligned} \mathbb{E}(\pi_d) &= (b_d - c_d) \Pr \left( b_d < \frac{b_f(c_f; p(d), d)}{1 - p(d)} \right) \\ &= (\tilde{b}_d - c_d) \Pr \left( \tilde{b}_d < \tilde{b}_f(c_f; t(1 - d), d) \right) = \mathbb{E}(\tilde{\pi}_d), \end{aligned} \quad (25)$$

Likewise, using a change of variables from  $b_f$  to  $(1 - p(d))\tilde{b}_f$ , equilibrium expected foreign

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<sup>22</sup>While this can be a linear function, i.e.  $t$  multiplied by  $1 - d$ , so that the tariff on cost equivalent would be on related to the share of  $c_f$  of foreign origin, we do not make this restriction.

profits under the price preference can be written as:

$$\begin{aligned}\mathbb{E}(\pi_f) &= (b_f - \delta(d; c_f))Pr\left(\frac{b_f}{1-p(d)} < b_d(c_d; p(d))\right) \\ &= ([1-p(d)]\tilde{b}_f - \delta(d; c_f))Pr\left(\tilde{b}_f < \tilde{b}_d(c_d; t(1-d))\right) = \mathbb{E}(\tilde{\pi}_f).\end{aligned}\quad (26)$$

There is equivalence in expected profits for both firms for this combination of policies. Moreover, since this is true for any value of  $d$ , the foreign firm's choice of  $d$  is identical under both policies. Furthermore, as net of tariff expected payments to the foreign firm under these two policies are the same, this equivalence extends to the government under the same conditions as discussed above. That said, just as in the baseline case, such equivalence can break down if there are limitations on policies. For example, as noted above, many domestic content-contingent price preferences are step functions; i.e., there is a price preference when  $d$  is below some threshold and none if the foreign firm meets this minimum standard. As such, this restriction on the price preference policy space can break equivalence just as restrictions on tariff policy space due to factors such as trade agreements did in the baseline.

## 4 Conclusion

When awarding government contracts, governments balance several considerations beyond the price paid, in particular, domestic firm performance. The literature has identified how this, as well as cost asymmetries across firms, can give rise to the use of price preferences under which the contract only goes to the foreigner if they underbid their domestic competitor by a sufficiently large amount. Although this practice has been addressed by the GPA agreement, other forms of protection remain. Here, we study the use of tariffs which, in addition to being discriminatory, generate revenues that may not be equivalent to expenditure savings. We demonstrate four aspects of this alternative form of protection in procurement. First, for each linear price preference, there is an equivalent ad valorem tariff from the firms'

perspectives. Furthermore, when a dollar of tariff revenues are as valuable as a dollar reduction in the price paid, the same equivalence extends to the government. Second, when cost distributions are identical, both protection regimes result in positive levels of protection. As such, simply banning price preferences is unlikely to stop protection in procurement auctions. Third, both the linear price preference and its equivalent tariff are less desirable than the theoretically optimal but unobserved in practice non-linear price preference. And finally, depending on the responsiveness of tariff revenues and the relative value of tariff revenues in the government's objective, moving from a price preference to a tariff can reduce protection and increase world welfare even as it reduces that of the government.

Combining these results suggests that while eliminating price preferences may help to open borders, they do not necessarily do so. However, when embedded into other agreements which limit the use of tariffs (as in the WTO), they may form an effective part of an overall battle against protectionism. In other words, one would expect the GPA to be more successful than other similar agreements *because* it is between WTO members that already have reciprocal tariffs agreements in place.

Although we do not examine our model's predictions empirically, it does suggest some potentially fruitful avenues. For example, in estimating the trade impact of procurement policy, it may be necessary to control for tariffs and tariff-limiting trade agreement membership since the impact of eliminating price preferences would have a different effect in a WTO member (where tariffs are bound) and a non-member (where tariffs can be altered to substitute for the change in price preferences). In addition, the willingness to sign a reciprocal agreement limiting price preferences may depend on whether one, both, or neither nation has limits on its tariff policy.

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# A Appendix

## A.1 An Alternative Proof of Equivalence

Here we show the equivalence between a price preference and a tariff for not necessarily linear price preferences/tariffs.

Each firm is endowed with a cost  $c_i$  and submits a bid  $b_i$  based on that. The government has a price preference for the domestic firm of  $P(b_f)$ . This means that if  $b_d < b_f + P(b_f)$  then the government purchases from it. Under a tariff, the government charges the foreign firm  $T(\tilde{b}_f)$  should it win, which happens so long as  $\tilde{b}_d > \tilde{b}_f$ . This is equivalent to the price preference if  $\tilde{b}_d = b_d$ ,  $\tilde{b}_f = b_f + T(\tilde{b}_f)$ , and  $T(\tilde{b}_f) = P(b_f)$ . Note that this would also imply that bid functions are such that  $b_d^t(c_d) := b_d^p(c_d)$  and  $b_f^t(c_f) := b_f^p(c_f) + P(b_f^p(c_f))$  form an equilibrium in the equivalent tariff game.

One can see this by looking directly at the two mechanisms: one transfers  $t_i(m_d, m_f)$  to player  $i$  and receives the object from player  $i$  with probability  $a_i(m_d, m_f)$  the other does so with transfer rule  $\tilde{t}_i(m_d, m_f)$  and  $\tilde{a}_i(m_d, m_f)$ . In our case, if  $t, a$  corresponds to the price preference and  $\tilde{t}, \tilde{a}$  corresponds to the equivalent tariff, then  $t_i(m_d, m_f) = \tilde{t}_i(m_d, f(m_f))$  and  $a_i(m_d, m_f) = \tilde{a}_i(m_d, f(m_f))$  where  $f(m) = m + P(m)$ . The function  $P(m)$  is the price preference given to player 1, that is,

$$a_d(m_d, m_f) = \begin{cases} 1 & \text{if } m_d < m_f + P(m_f), \\ 1/2 & \text{if } m_d = m_f + P(m_f), \\ 0 & \text{if } m_d > m_f + P(m_f). \end{cases}$$

We also have  $a_f(m_d, m_f) := 1 - a_d(m_d, m_f)$ . Note that how we set  $\tilde{a}_d$  and  $\tilde{a}_f$ , we have

$$\tilde{a}_d(m_d, m_f) = \begin{cases} 1 & \text{if } m_d < m_f, \\ 1/2 & \text{if } m_d = m_f, \\ 0 & \text{if } m_d > m_f. \end{cases}$$

If  $m_d^*(c_d), m_f^*(c_f)$  is an equilibrium of mechanism  $t, a$ , then, for all  $c_i$ , the choice  $m_i^*(c_i)$  equals

$$\arg \max_{m_i(c_i)} E[t_i(m_i(c_i), m_{-i}^*(c_{-i})) - a_i(m_i(c_i), m_{-i}^*(c_{-i}))c_i].$$

However,  $\tilde{m}_d^*(c) := m_d^*(c), \tilde{m}_f^*(c) := f(m_f^*(c))$  would be an equilibrium of mechanism  $\tilde{t}, \tilde{a}$  since

$$\begin{aligned} E[\tilde{t}_i(\tilde{m}_d^*(c_d), \tilde{m}_f^*(c_f)) - \tilde{a}_i(\tilde{m}_d^*(c_d), \tilde{m}_f^*(c_f))c_i] &= E[\tilde{t}_i(m_d^*(c_d), f(m_f^*(c_f))) - \tilde{a}_i(m_d^*(c_d), f(m_f^*(c_f)))c_i] \\ &= E[t_i(m_d^*(c_d), m_f^*(c_f)) - a_i(m_d^*(c_d), m_f^*(c_f))c_i]. \end{aligned}$$

Hence, the respective choice of  $m_i(c_i)$  will maximize expected payoff.