# The honest truth about true pricing

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# The honest truth about true pricing*

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Abstract: *True pricing has progressed from an abstract notion to a real life phenomenon as a way to make consumers aware of the genuine costs to society of products. Our paper analyzes the impact of true prices on competition. Our model uses a straightforward differentiated Bertrand set-up where consumers can choose to pay the true price or the normal price. There are consumers who strongly prefer not to cause externalities. These consumers will opt to pay the true price. Other consumers receive less disutility of causing externalities. They will pay the normal price. Our findings are that setting the true price can be an equilibrium strategy for one or both firms. True prices can be welfare enhancing, but it comes at a cost. True prices harm consumers that do not value external effects as it raises the normal price. A comparison of true prices with taxation of the external effect shows that both can be socially optimal. Taxation is better because it covers both types of consumers, and worse because it overcorrects in the presence of market power. The paper demonstrates the value of analyzing competitive effects of environmental initiatives.*

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## 1 Introduction

There are several ways to deal with negative external effects. Among those, changing relative prices quickly comes to an economist's mind. Governments often impose taxes or grant subsidies for this reason. A recent development is that firms set so-called 'true prices'. The true price is the price that includes all costs of production and consumption, including negative externalities for society. The idea is that a true price steers consumers towards more sustainable options, which would in turn reward sustainable production (Baltussen and Woltjer, 2023). Proponents see several mechanisms through which true pricing may contribute to a sustainable economy. True pricing can make external costs transparent and create consumer preferences for products with a lower externality, enable businesses to develop strategies to reduce externalities, enable the collection of payments from consumers for compensation, and shape government policy to incentivize sustainable and inclusive economic decision-making (True Price Foundation, 2019). Application of true pricing naturally requires an estimate of external costs, for which a number of methods exist (de Adelhart Toorop, 2021).

Some firms have recently experimented with charging true prices. Penny, a German supermarket, charged the true price for nine products for one week (Penny, 2023). Dutch supermarket Albert Heijn gave buyers of coffee to go a choice: pay the standard price or pay the true price. Steiner et al. (2023) report that the Penny campaign increased awareness of the social impact of consumption, and that some consumers were willing to substitute towards organic options or to pay the true price. Albert Heijn (2023) reports that 15% of consumers actually paid the true price, but it found no substitution to more sustainable options. Both supermarkets donated the extra revenues from true pricing to environmentally focused charities. Motivated by these examples, we ask ourselves: what happens to prices and price competition if firms offer consumers the choice between paying the standard price and the true price?

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To shed light on this issue we build a simple model of heterogenous price competition between two firms. Firms offer one product of a given quality. They can sell it at two prices: a standard price and the standard price plus the externality. Consumers can choose which price to pay. Reflecting consumer heterogeneity in willingness to pay for sustainability (Katt and Meixner, 2020; White et al., 2019; Li and Kallas, 2021; Taufik et al., 2023), there are two types of consumers in the model: those with a high concern for sustainability and those with a low concern for sustainability (relative to monetary payoffs). High types are willing to pay the true price.

We assume that if consumers pay the true price the extra revenue is used to fully compensate the externality. If firms offer a true price, we assume they raise the price by the size of the externality. Our motivation for this assumption is that the firms that apply true pricing in practice use estimates of the externality provided by third parties (as in the supermarket cases mentioned). So a scenario where firms can credibly commit to the true price seems sufficiently plausible in practice. In the discussion we relax this assumption.

Our paper finds that, relative to the benchmark case where firms set one standard price, true pricing increases the standard price. The intuition is that the high types derive more utility from a transaction when the social cost is fully compensated. True pricing therefore makes a firm more attractive to the average consumer, which implies that the firm optimally increases its standard price. As a result, low types are worse off. Competition does not completely erode this effect because true pricing improves both firms' attractiveness. Hence we conclude that true pricing has distributional consequences: the utility of high types increases whereas that of low types decreases.

At the heart of this result lies a restriction on firms to differentiate prices between low and high types: the distance between the standard price and the true price must be equal to the social cost, or else the firm would be overcharging high types for the social cost (which we rule out since we focus on the case where firms apply true pricing honestly). This implies that firms optimize the standard price for the average consumer rather than setting a price for each segment. Nothing, however, prevents firms from sharing part of the social cost with consumers who pay the true price. In fact, some respondents in Albert Heijn's experiment wondered why Albert Heijn did not pay the true price itself (Albert Heijn, 2023).

In an extension where firms can pay part of the externality, we find there are equilibria in which firms find it optimal to do so, but it never pays the full external cost. If the co-payment is positive, firms increase the standard price. Co-payment may thus reinforce the distributional consequences of true pricing at the detriment of low types. Effectively, copayment allows for greater price discrimination between types $H$ and $L$, where it lowers the effective price for the low demand consumers (type $H$) even further. However, whereas true price is free, copayment raises the marginal costs to the firm. Therefore we find that this is profitable only if the demand from type $H$ is not too large relative to the need for additional price discrimination.

In our model, true pricing can contribute to sustainability as some consumers are willing to more, if the additional amount is used to remove externalities. But how effective is true pricing in promoting sustainability compared to other methods? In particular, is true pricing doing a better job than the classic case of taxation? We conduct a simplified comparison in which we assume that the funds raised through taxation are used to remove the externality completely. Taxation and true pricing are thus assumed equally effective in removing externalities. We find that taxation can be better, because it causes fewer externalities as no consumer can opt out. However, taxation can also be worse since a tax equal to the externality overcompensates for the externality in case of market power. Taxation also has distributional consequences, again unfavourable to the low types. In particular, the negative distributional consequences for consumers unwilling to pay the true price are greater from taxation than from true pricing.

Our paper makes three contributions. First, the paper adds to a growing policy and scientific literature on the potential of true cost accounting. The underlying ambition of this literature is to identify opportunities for true pricing to contribute to a more sustainable economic system (see e.g. Gemmill-Herren et al., 2021; de Adelhart Toorop et al., 2021). Hendriks et al. (2021) list a number of pathways through which true pricing can improve sustainability. Among the market-based initiatives, they list providing transparency on social costs, steering consumption towards low social cost options, providing information to business to reduce their social cost, and the payment of social costs to fund the removal of the externality itself. We focus on the case where firms actually charge the true price. This brings price competition into the picture, hence our use of industrial organization models. To the best of our knowledge, our paper is the first to apply this approach to true pricing. This approach reveals the interrelationship between true pricing and competition. It also allows us to compare the effectiveness of true pricing to taxation from a social welfare perspective.

The second contribution is that this paper relates to the industrial organization literature by applying standard price competition models to the relatively new phenomenon of true pricing. Within the industrial organization literature, our paper is most closely related to research on competition between green and brown products. Much of this literature focuses on strategic product design where firms choose a quality level (or levels) taking into account consumer preferences (which may or may not include sustainability concerns). Conrad (2005) develops a spatial model of product differentiation where two firms first choose a quality level and then compete in prices. A higher quality level means more hedonic utility from the product, but quality is assumed to correlate negatively with environmental friendliness. By choosing a quality level firms choose how much they cater to the preferences of environmentally concerned consumers, who are willing to forego hedonic utility if the product is more sustainable. Conrad (2005) shows that the firms strategically differentiate their product in terms of quality/environmental friendliness in order to limit price competition. Eriksson (2004) finds that profit-maximizing firms undersupply green products even if consumers care for the environment, as long as consumers do not fully internalize the externality. Product differentiation drives this result, as differentiation on greenness shields firms from price competition.

Finally, our paper contributes to the recent literature on cases where firms can compete in multiple quality dimensions and/or consumers have private information about their valuation of quality (e.g. Burani and Mantovani, 2020). In our model strategic product design plays no role. In the horizontal dimension which in our model lines up with preferences other than sustainability concerns - it is absent. In the vertical dimension differentiation takes a digital form which is dictated by the nature of true pricing. Firms can offer their product at the true price, but if they do, they must rely on third parties to provide them with objective information on the externality. This is how firms engaging in true pricing operate in practice and also seems important for gaining consumer trust in true pricing. So firms cannot choose the level of greenness of their product, but they can choose whether or not they offer the true price. We show that if firms incur a fixed cost for offering the true price, there exists a range of fixed costs for which only one firm offers the true price. Also, note that true pricing differs from offering a green product because green products are more sustainable than brown products but typically also differ in terms of other quality dimensions, such as shelf life, taste, and effectiveness of chemical components such as in cleaning. Finally, Van der Made and Schoonbeek (2007) consider a game where an NGO can make consumers care more about environmental externalities. Like us, they study the impact of these preferences on competition. Unlike us, they consider the incentives of new firms with greener alternatives to enter the market. They show that the introduction of greener products can increase total pollution via increased demand.

Our model makes a number of simplifying assumptions that places a full appreciation of true pricing out of reach. We consider the following as key assumptions: i) true pricing has no information value to consumers as they already know the externality, ii) consumers can only buy one product with a given sustainability level (quality), and iii) firms use the proceeds from true pricing to effectively compensate the externality. Section 7 discusses the implications of these assumptions.

The remainder of the paper is organised as follows. Section 2 introduces the model and main assumptions. Section 3 studies the effect on market outcomes if some, but not all, firms offer the true price. Section 4 analyses the case where firms are free whether to implement the true price or not. Section 5 extends the model to allow for the firm sharing the social cost with consumers that pay the true price (co-payments). Section 6 compares market outcomes to the case of government taxation. In section 7 we discuss the merits of true pricing in light of our results, and we discuss how the appreciation of true pricing depends on the key assumptions that we make. All proofs are relegated to the appendix.

## 2 A model of price competition with true prices

As our base model, we use a standard differentiated Bertrand model to analyse how true pricing affects price competition. Consider a market with two firms, $A$ and $B$, selling a heterogenous product. We denote an arbitrary firm by $i$ and its competitor by $j$. Firms set prices simultaneously, where $p_i$ denotes the price set by firm $i$. The residual demand for firm $i$, absent any externalities, is equal to

$$D_i^0\left(p_i, p_j\right) = a - bp_i + dp_j, \tag{1}$$

where $b > d > 0$. Marginal costs are constant and equal to $c$.

We model a true price (TP) in a very simple way. Each purchase causes a negative externality $X$. When firm $i$ introduces a TP, it offers the consumers a choice. They can either pay the *standard price*

$p_i$ and cause the externality, or pay the TP $p_i + X$ and prevent the externality. In this sense, our base model incorporates an ideal version of true pricing. None of the additional money raised by customers paying the TP is kept for profits. Moreover, paying the TP is effective in preventing all of the negative externalities of that purchase.

Consumers in our base model prefer not causing the externality. In particular, consumer $k$ is willing to pay $\omega_k X$ more, if his purchase would cause no externality, where $\omega_k \in \{L, H\}$, $H > 1 > L \geq 0$. Let $\Pr(\omega_k = H) = \alpha$ and $\bar{\omega} = (1-\alpha) L + \alpha H$. We focus on the cases where, in equilibrium, both firms face positive demand from both types of consumers.[1] The *effective price* that consumer $k$ pays at firm $i$, if she does not pay the TP, is therefore equal to $p_i + \omega_k X$. So, if neither firm offers the TP, the residual demand for firm $i$ equals

$$\begin{aligned} D_i^X(p_i, p_j) &= a - b(p_i + \bar{\omega} X) + d(p_j + \bar{\omega} X) \\ &= a - bp_i + dp_j - (b-d)\bar{\omega} X. \end{aligned} \tag{2}$$

By $b > d$, it follows that demand is lower when the average consumer is more bothered by the externalities caused.

If firm $i$ offers a true price, its consumers can choose whether to pay the standard price $p_i$, or the true price $p_i + X$. If consumer $k$ opts not to pay the true price, his effective price at firm $i$ is unchanged: $p_i + \omega_k X$. If instead $k$ chooses to pay the true price, no externality is caused and the effective price that $k$ pays at $i$ is equal to $p_i + X$.

We call consumption and demand for which the TP is payed *compensated consumption* or *compensated demand*. Consumption and demand for which the TP is not payed is refered to as *uncompensated*. We say that fewer externalities are caused if uncompensated consumption decreases.

Firms maximize their profits. We consider the Nash equilibria of this game.

# 3 How introduction of a TP affects the market

In this section, we study how the introduction of the TP affects the market outcomes. Therefore we focus on the case where one firm has implemented the TP while the other firm has not. Without loss of generality, we assume that firm $A$ offers the TP and that firm $B$ does not. To study the effect of the implementation, we first consider the benchmark case, where neither firm offers the TP. Then we consider the case where only $A$ does offer the TP.

## 3.1 Benchmark

In this section we establish our benchmark (BM). Suppose that neither firm offers a TP.

**Lemma 1** *Consider the base game and assume that neither firm offers a TP. In the equilibrium of that subgame, each firm sets price*

$$p^{BM} = \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d},$$

*which results in the following demand and profits for each firm*

$$\begin{aligned} D_i^{BM} &= b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} \\ \pi_i^{BM} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d}\right)^2 \end{aligned}$$

This lemma functions as our benchmark throughout the paper, as it represents the current situation without a TP. In addition, it shows that if consumers are aware of the externalities caused and dislike those externalities, then demand for the product will be lower. Consequently, firms charge a lower price, sell less and make less profits.

Note that type $L$ consumers benefit from the presence of type $H$ consumers. The reason is that the externality lowers the optimal price because the willingness to pay from consumers is negatively affected by the disutility incurred. The higher this disutility, the more the price is lowered. So the larger the share of type $H$ consumers is, the lower the price that consumers have to pay. In other words, if firms

[1] Appendix B shows that this is true for a range of parameters. The specific restrictions can be found there.

can price discriminate between the two types, the price for type $L$ consumers would be higher than $p^{BM}$, while the price for type $H$ consumers would be lower than $p^{BM}$. In the following section we will find that a TP allows a firm to price discriminate to some extent between type $L$, by raising the standard price, and type $H$, for whom the effective price is lowered.

### 3.2 One firm offers a True Price

Now consider the case in which one firm offers a TP. Without loss of generality, we assume that this is firm $A$. We call this the TPA case.

To derive the new demand, we need to know which customers will choose to pay the TP when they buy at $A$. Customers can choose between causing the externality, at a cost of $\omega_k X$ to customer $k$, or to pay the higher TP, at a cost of $X$. Paying the TP is thus optimal for customer $k$ if $\omega_k \geq 1$. If instead $\omega_k < 1$ then paying the normal price is better.

**Lemma 2** *Suppose firm $i$ offers a TP. Consumer $k$ prefers to pay the TP when buying at $i$ if and only if $\omega_k \geq 1$.*

Effectively the TP lowers the price at firm $A$ by $(H-1)X$ for each customer $k$ with $\omega_k = H$. In other words, share $\alpha$ of the population experiences a cost reduction of $(H-1)X$ at firm $A$. This results in the following demand functions:

$$\begin{aligned} D_A(p_A, p_B) &= a - bp_A + dp_B - (b-d)\bar{\omega}X + \alpha b(H-1)X, \\ D_B(p_B, p_A) &= a - bp_B + dp_A - (b-d)\bar{\omega}X - \alpha d(H-1)X. \end{aligned}$$

We see that, given prices, introduction of a true price by $A$ causes $\alpha d(H-1)X$ demand to shift from $B$ to $A$. Moreover, it attracts $\alpha(b-d)(H-1)X$ additional demand because $H$ types now buy more. So the TP increases demand from type $H$ consumers at firm $A$, while it reduces that demand at type $B$. Using these demand functions we obtain the following equilibrium.

**Proposition 1** *Consider the base game and assume that only one firm, firm $A$, offers a TP. In equilibrium, prices of firms $A$ and $B$ are respectively*

$$\begin{aligned} p_A^{TPA} &= p^{BM} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X, \\ p_B^{TPA} &= p^{BM} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X. \end{aligned}$$

*which results in the following demand and profits.*

$$\begin{aligned} D_A^{TPA}\left(p_A^{TPA}, p_B^{TPA}\right) &= b\left(\tfrac{D_i^{BM}}{b} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right), \\ D_B^{TPA}\left(p_B^{TPA}, p_A^{TPA}\right) &= b\left(\tfrac{D_i^{BM}}{b} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X\right), \end{aligned}$$

$$\begin{aligned} \pi_A^{TPA}\left(p_A^{TPA}, p_B^{TPA}\right) &= b\left(\tfrac{D_i^{BM}}{b} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right)^2 \\ \pi_B^{TPA}\left(p_B^{TPA}, p_A^{TPA}\right) &= b\left(\tfrac{D_i^{BM}}{b} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X\right)^2 \end{aligned}$$

What do we learn by comparing Lemma 1 and Proposition 1? First, we see that by offering a TP, firm $A$ creates additional value, a better product, to all consumers with $\omega > 1$. This does not only raise the demand of type $H$ consumers who, without a TP, would already buy from $A$. It also shifts some of the demand from $H$ consumers from $B$ to $A$. This increase in demand depends both on the share of consumers willing to pay the TP, $\alpha$, as well as on the size of the benefit a TP provides, $(H-1)X$.

To optimally profit from this increase in residual demand, firm $A$ increases both its price (profit margin) as well as the quantity that it sells. Similarly, $B$ optimally adjusts to the reduction in its residual demand by reducing its price and quantity. All of these changes scale in $\alpha(H-1)X$. The net price difference, $p_A^{TPA} - p_B^{TPA} = \frac{b+d}{2b+d}\alpha(H-1)X$, increases in $d$, $\alpha$, $H$, and $X$, and decreases in $b$. Note that demand from type $L$ consumers shifts towards $B$. The reason is that the TP does not provide additional value to type $L$ consumers, while the price shifts of $A$ (up) and $B$ (down) makes firm $B$ a more attractive option.

It follows that the effects of a TP are small if ($i$) only few consumers care enough to pay the TP, ($ii$) if consumers who pay the TP do not care much about it, or ($iii$) if the externalities themselves are small. The effects are likely to be large if people care a lot about the externalities caused.

Effectively, the TP allows firm $A$ to second degree price discriminate between high demand consumers (type $L$), and low demand consumers (type $H$). The standard price for type $L$ at firm $A$ went up:

$$p_A^{TPA} = p^{BM} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha\,(H-1)\,X > p^{BM},$$

therefore the effective price for these consumers went up as well. In contrast, for type $H$ the effective price was reduced:

$$p_A^{TPA} = p^{BM} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha\,(H-1)\,X < p^{BM} + HX, \tag{3}$$

by $\frac{2b^2-d^2}{4b^2-d^2} < 1$, $\alpha < 1$ and $(H-1) < H$. In other words, at firm $A$ the TP increases the price for high demand consumers, and lowers it for low demand consumers.

Clearly, firm $A$ profits and firm $B$ loses when $A$ offers the TP. What about the consumers? Let us call consumers who would buy from firm $i$ in the BM case as $i$-consumers, and let 'new consumers' be consumers who do buy in the TPA case but did not in the BM case. It is easy to see that all $B$-consumers gain as $p_B^{TPA} < p_B^{BM}$. Moreover, $A$-consumers who now pay the TP gain, as their effective price has decreased, see (3). $A$-consumers lose if they continue to buy at $A$ without paying the TP, as they now pay a higher price. Similarly, $A$-consumers who stop buying lose. $A$-consumers who switch to $B$ because of the price difference ($p_A^{TPA} > p^{BM} > p_B^{TPA}$) may be better or worse off, depending on whether $p^{BM} - p_B^{TPA}$ is smaller or larger than their preference for shopping at $A$. New consumers apparently get a better deal than before, and therefore gain. The following proposition summarises these findings and derives results on total profits, total demand and total externalities.

**Proposition 2** *Consider the base game in which only firm A offers a TP. Compared to the benchmark, total demand increases, total profits increase, and fewer externalities are caused. In particular, firm A benefits unambiguously, and firm B loses unambiguously. New consumers gain, as do B-consumers. A-consumers who pay the TP gain. A-consumers who stop buying or continue to pay the standard price at A lose. The effect on A-consumers who switch to B is ambiguous.*

In the Proposition above, we identify explicitly the consumers who lose due to the introduction of true pricing. Our results show that true pricing has distributional consequences. Consumers who do not pay the true price, and hence experience the same utility from consumption as before, nevertheless pay a higher price. This is because the TP allows for second degree price discrimination: it allows firm $A$ to lower the price for low demand consumers (type $H$) while it increases the effective price for high demand consumers (type $L$). Obviously, the condition that the price difference between the TP and the standard price is equal to the externality $X$, does not permit firm $A$ to price discriminate optimally. In Section 5 we consider a case where $A$ can reduce the price difference by paying part of the TP itself.

Our result suggests one explanation for anti-woke sentiments. Even though the TP is nominally '*voluntary*', the customers of $A$ who do not pay the TP still pay more! In that sense, the catering to type $H$ consumers (offering the TP) seems to hurt them. If the standard price increase is viewed in this light, even people with $\omega_k \in (0,1)$ may dislike the voluntary TP.

# 4 Endogenous choice of TP

In the previous section, we study market outcomes given the adoption of a TP. In this section, we study whether firms want to introduce a TP in the first place. To do so, we add a stage before the price setting stage, where firms choose sequentially whether to adopt a TP. Without loss of generality, first firm $A$ chooses whether to offer a TP. Then, $B$ chooses whether to introduce a true price. Lastly, $A$ and $B$ simultaneously set their standard prices and profits are realized. We solve for the subgame perfect Nash equilibria.

## 4.1 Analysis of the general model

We first need to derive firm profits in the market equilibrium given the choice for or against offering a TP. In Section 3 we have derived the profits in case neither firms offers a TP and where just one firm offers a TP. We now consider the subgame in which both firms offer a TP. We use $TP2$ to denote the equilibrium market outcomes for this subgame.

As explained in the main analysis, adopting a TP effectively gives customers with $\omega = H$ a price reduction of $(H-1)X$. Therefore, the residual demand for firm $i$ is equal to

$$D_i(p_i, p_j) = a - bp_A + dp_B - (b-d)\bar{\omega}X + \alpha(b-d)(H-1)X$$

**Lemma 3** *Consider the TPBoth game, and consider the subgame after both firms have chosen to offer a TP. In that subgame, for each $i$, the equilibrium price, quantity and profits are as follows:*

$$\begin{aligned} p^{TP2} &= p^{BM} + \tfrac{(b-d)}{2b-d}\alpha(H-1)X \\ D^{TP2} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\tfrac{b-d}{2b-d}(H-1)X\right) \\ \pi^{TP2} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\tfrac{b-d}{2b-d}(H-1)X\right)^2 \end{aligned}$$

As before here TP raises the demand and optimal price of the firm introducing the TP. The reason is again that none of its customers will value the product less than before, whereas some customers value it more.

Also as before, when a firm introduces the TP its competitor loses demand. In this case, if only $A$ has a TP, some of the customers with $\omega = H$ who would normally prefer shopping at $B$ now prefer shopping at $A$, because $A$ offers the TP. If $B$ now also introduces a TP, those customers would prefer $B$ again (at equal prices), thus demand shifts back to $B$. Overall, however, both firms face higher demand than if neither firm offers a TP, because the firms now provide a better product to some customers. As a result we see the following ranking of prices[2]:

$$p_A^{TPA} > p^{TP2} > p^{BM} > p_B^{TPA}$$

Again total surplus has increased as all transactions are voluntary and some transactions provide more value. However, now all consumers with $\omega = L$ lose. If only firm $A$ offers a TP, firm $B$ lowers its price benefitting some of the consumers who are unwilling to pay the TP. Now none of the consumers with $\omega < 1$ are benefitting. Instead, all of them face higher prices. From that perspective, it is understandable why the introduction of a TP may encounter negative sentiments even from people who appreciate the goals that the TP is trying to achieve (in case $L > 0$).

As introducing a TP is always profitable, this results in the following subgame perfect Nash equilibrium.

**Proposition 3** *Consider the TPBoth game. Then in the subgame perfect equilibrium the strategy of each firm $i$ is as follows:*

$$\text{Always offer TP and charge } p_i = \begin{cases} p^{BM} & \text{if neither firm introduced a TP} \\ p_A^{TPA} & \text{if } i \text{ is the only firm with a TP} \\ p_B^{TPA} & \text{if } i \text{ is the only firm without a TP} \\ p^{TP2} & \text{f both firms have a TP} \end{cases}$$

## 4.2 Costly implementation of a TP

Above we have established that offering a TP is profitable for both firms. Yet in reality, most firms do not offer a TP. There are two obvious explanations why firms have not introduced a TP. First, TP may be too new an idea. In that case firms have not introduced it, because they were not aware of the possibility to do so. Second, the implementation of a TP may be costly. If a firm offering a TP incurs an additional fixed cost $F$ and not enough consumers care enough about the TP, then implementation of a TP may

[2] Observe that $p_i^{TP2} = p^{BM} + \frac{(b-d)}{2b-d}\alpha(H-1)X = p^{BM} + \frac{(b-d)(2b+d)}{(2b-d)(2b+d)}\alpha(H-1)X = p^{BM} + \frac{2b^2-d^2-bd}{4b^2-d^2}\alpha(H-1)X < p^{BM} + \frac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X = p_A^{TPA}$.

not be worthwhile. In this subsection, we consider the latter option. In particular, we are interested if it is possible that some but not all firms adopt a TP.

The answer to this question depends simply on the comparison of $\left(\pi_A^{TPA} - \pi^{BM}\right)$ with $\left(\pi^{TP2} - \pi_B^{TPA}\right)$. If the latter exceeds the former, then whenever a firm is willing to be the only firm with a TP, the other firm will prefer to have a TP as well. The next proposition shows that this does not hold. So, the benefit to a firm of offering a TP is larger if the other firm does not offer a TP than if it does.

**Proposition 4** *Consider the TPBoth game, with one adjustment. Any firm introducing a TP incurs a fixed cost equal to F. Then there exists* $F^*$ *and* $F^{**}$, $0 < F^* < F^{**}$, *such that in the subgame perfect Nash equilibrium:*

- *both firms offer a TP if* $F < F^*$;
- *neither firm offers a TP if* $F > F^{**}$.
- *only firm A offers a TP if* $F \in (F^*, F^{**})$.

It follows that if costs of implementation $F$ are moderate compared to the average valuation for a TP, $\alpha (H-1) X$,[3] then it is optimal for some but not all firms to implement a TP.

# 5 Copayments

When Albert Heijn experimented with the TP, a questionnaire revealed that some consumers wondered why the whole TP was paid by consumers (Albert Heijn, 2023). This raises the question whether a firm with a TP would prefer to pay part of the true price itself? In this section, we show that this can indeed be the case, even when (i) consumers do not care about a fair division the true price and (ii) firms care only about profits.

To keep things simple, we assume that only $A$ has a TP. This corresponds to the case of moderate implementation costs (see Subsection 4.2). More importantly, it reflects the current situation where not all firms provide a TP.

Consider the basic model in which firm $A$ introduces a TP[4], but it also sets $\sigma$, $\sigma \in [0,1]$, the share of the TP that the consumer pays at firm $i$. The timing of the game is as follows. First, $A$ sets $\sigma$. Then both firms choose their prices simultaneously, and payoffs are realized. We call this the copayment game, denoted by $CPA$.

**Proposition 5** *Consider the copayment game and let* $\sigma^{CPA}$ *be the share of the TP that consumers pay in equilibrium. Then, there exists* $\hat{H} = \frac{(b-(b-d)L)}{d} > 1$ *such that* $\sigma^{CPA} \in (L, 1)$ *if* $H \in \left(1, \hat{H}\right)$ *and* $\sigma^{CPA} = 1$ *if* $H \geq \hat{H}$. *In particular,* $\sigma^{CPA} = \min\left\{\frac{b+Hd+(b-d)L}{2b}, 1\right\}$

As Proposition 5 shows, it can be profitable for firm $A$ to copay the true price. This may seem obvious. If $A$ pays share $(1-\sigma)$ of the TP itself, any consumer $k$ with $\omega_k > \sigma$ will choose to pay the TP. Clearly, copayments can result in additional demand for $A$.[5] Yet, in our model with $L < 1 < H$, this plays no role.[6] In particular, Proposition 5 shows that in equilibrium $\sigma > L$. The reason is simple. $A$ benefits from the TP because it allows $A$ to second degree price discriminate between consumers. This requires that different types of consumers would make different choices. At least some type must be willing to pay the TP, and at least some type must prefer not to. Thus, $A$ will choose $\sigma > \min_k \omega_k = L$.

Nonetheless, $A$ may prefer $\sigma < 1$ exactly because it wants to price discriminate. Introducing the TP, allows $A$ to lower the effective price to $H$ for free. This allows $A$ to increase its standard price. By introducing copayments, $A$ can lower the effective price for $H$ even further, and increase the standard price even further. However, copayment increases the marginal cost of each TP sale. Whether this is

[3] Recall that the increase in profits from a TP is propotional to $\alpha (H-1) X$.

[4] We have shown the same in a model where $\omega$ is distributed uniformly on $[0, H]$, where $H > 1$.

[5] If people care about fairness and consider it fair that the firms pay part of the TP as well, demand can increase even more. This would further stimulate firms to donate part of the TP themselves. Proposition 5 shows that this consideration is not necessary for firms to be willing to copay the TP.

[6] Note that if $L < H < 1$, then copayments can be used to convince type $H$ consumers to pay the TP. This can be profitable because it allows for price discrimination, which is impossible with $\sigma > 1$. However, this lowers joint surplus, as the total benefit of the TP to the firm and consumer, $HX$, is exceeded by its total cost, $\sigma X + (1-\sigma) X = X > HX$.

worth it, depends on $H$. The higher $H$ is, the more TP sales $A$ has without copayment, and the more costly introduction of copayment is.

Moreover we see that $\hat{H}$ is decreasing in $L$. Thus the larger $L$ is, the smaller $H$ must be to make copayments profitable. The idea is that as $L$ becomes larger, given $H$, the less important it is to price discriminate. Therefore the maximum $H$ for which copayment is worthwhile, $\hat{H}$, decreases too.

In summary, firms may prefer to copay the TP even without consumers demanding so. However, if TP is too popular among $H$-types, copayment is too costly.

# 6 Comparison with internalisation via taxation

We have seen that the TP helps to reduce the externalities. In this section we compare the implementation by firms of a TP to the imposition of a tax by the government, and compare the two methods.[7]

To allow for as fair a comparison as possible, we assume that the two methods are equal in as many aspects as possible. In particular, we make the following three assumptions. First, both methods are costless to implement. This implies that in the TP case, both firms implement the TP. This also ensures that TP is offered across the board, just as a tax is imposed across the board. Second, both methods are fully effective: they remove (or fully compensate) the externality. This implies that consumers who pay the tax do not have a disutility of causing externalities. Third, the tax equals the externality $X$, just as the TP does.[8]

To keep things simple we assume the weight that society attaches to the externality is 1. This implies that in the TP case, if consumer $k$ does not pay the TP on one purchase, then the cost to society are equal to $(1+\omega_k)\,X$. In that sense, society as a whole has an incentive to prevent the externalities for any $L>0$.

In order to calculate and compare the consumer surplus from taxes and TP, we need to specify the utility that consumers derive from the demand. For the analysis below, we assume that the consumer surplus is the same as it would be using a utility function in the style of Singh and Vives (1984).

**Lemma 4** *Consider an economy consisting of two sectors, namely a duopoly with firms $A$ and $B$, with residual demand function*

$$D_i\left(p_i,p_j\right)=a-bp_i+dp_j$$

*and a competitive numeraire sector. Let the utility from each sector be additively separable, and let the marginal utility of consumption in the numeraire sector be constant. Then, absent externalities and taxes, the residual demand function can be the result of a representative consumer that derives the following utility from its consumption from the duopolists' market:*

$$U\left(q_i,q_j,m\right)=\gamma\left(q_A+q_B\right)-\frac{\beta}{2}\left(q_A^2+2\theta q_A q_B+q_B^2\right),$$

*where $\gamma=\frac{a}{b-d}$, $\beta=\frac{b}{2(b-d)(b+d)}$, and $\theta=\frac{d}{b}$. The consumer surplus from the duopolists' market is equal to*

$$CS\left(q,p\right)=2\left(\frac{a}{b-d}-p\right)q-\frac{1}{2(b-d)}q^2 \tag{4}$$

In the analysis below, the consumer surplus is assumed to be equal to (4). The costs of externalities are deducted separately. We refer to this basic model with taxation as the tax game, denoted by *tax*.

## 6.1 The tax equilibrium

Suppose the government wants to reduce the externalities by introducing a per unit tax equal to the externality, $X$, on the consumers. This tax is used exclusively to fully neutralize the externality. Therefore, in the tax model, residual demand functions are equal to

$$D_i^{tax}\left(p_i,p_j\right)=a-b\left(p_i+X\right)+d\left(p_j+X\right)$$

This result in the following equilibrium.

[7] Note that this section can also interpreted as the case where firms impose a *non-voluntary* TP which all customers are forced to pay.

[8] Observant readers will recognize that this is not the optimal level of taxation. In this model, firms have market power. This market power already reduces the quantity sold. Therefore, a lower tax is sufficient to reduce the quantity to the efficient quantity in this market. From a practical point of view, taking into account the level of market power when setting taxes is likely to be quite hard, even when comparing it to imposing a tax equal to some estimate of the externalities.

**Lemma 5** *Consider the tax game. Then in equilibrium the price, quantity and profits of each firm are equal to:*

$$\begin{aligned}
p^{tax} &= \tfrac{a+bc-(b-d)X}{2b-d} \\
D^{tax} &= b\tfrac{a-(b-d)c-(b-d)X}{2b-d} \\
\pi^{tax} &= b\left(\tfrac{a-(b-d)c-(b-d)X}{2b-d}\right)^2
\end{aligned}$$

*Social welfare equals*

$$W^{tax} = \left(2\tfrac{a-(b-d)c-(b-d)X}{b-d} - \tfrac{1}{2(b-d)}D^{tax}\right)D^{tax}$$

*Consumers of type $L$ are worse of than in the benchmark, while consumers of type $H$ are better off: $p^{BM} + LX < p^{tax} + X < p^{BM} + HX$.*

As one would expect, the tax has distributional consequences in favor of consumers who prefer to prevent or compensate the externality.

Having derived the social welfare for the tax game, we now do the same for the case where both firms offer a voluntary TP.

## 6.2 Equilibrium welfare in the TP2 case

In the TP2 case, only type $H$ consumers pay the TP. This means that, in contrast to the tax case, some externalities are caused, namely equal to $X$ times the amount bought by type $L$ consumers. Let $D_i^{\omega=L} = (1-\alpha)D^L$ be the amount bought by consumers of type $L$ from firm $i$, where

$$\begin{aligned}
D^L &= a-(b-d)\left(p^{TP2}+LX\right) \\
&= a-(b-d)\left(\tfrac{a+bc-(b-d)(\alpha H+(1-\alpha)L)X}{2b-d} + \tfrac{(b-d)}{2b-d}\alpha(H-1)X\right) - (b-d)LX \\
&= b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\tfrac{b-d}{2b-d}\left((b-d)(1-L)+b(H-L)\right)X \\
&= D^{TP2} + \alpha(1-L)(b-d)X
\end{aligned}$$

Then the externalities caused in this equilibrium are equal to $2D_i^{\omega=L} = 2(1-\alpha)D^L$.

Note that the base price is higher under a TP than if a tax of $X$ is imposed. This is logical. Consider the demand under standard price $p$. For consumers with $\omega = H$, the effective price is $p+X$ both with a tax and with a TP. For consumers with $\omega = L$, the effective price with a TP, $p+LX$, is lower than the effective price under a tax, as these consumers will choose to incur the lower cost of causing the externality instead. Consequently, for any standard price $p$, demand is higher under a TP. Therefore the optimal standard price is higher under a TP than with the equivalent tax.

**Lemma 6** *Consider the equilibrium of the TP2 game. Welfare equals*

$$\begin{aligned}
W^{TP2} &= 2\left(\tfrac{a-(b-d)c}{b-d}\right)D^{TP2} - \tfrac{1}{2(b-d)}\left(D^{TP2}\right)^2 - 2\left(1+(1-\alpha)L\right)D^{TP2}X \\
&\quad -2\alpha(1-\alpha)(b-d)(1-L)LX^2
\end{aligned}$$

*Moreover, the standard price is higher than in the tax game, $p^{TP2} > p^{tax}$, while the effective price for type L consumers is lower, $p^{TP2} + LX < p^{tax} + X$. Consumers with $\omega = L$ are better off in the TP2 game, $p^{TP2} + LX < p^{tax} + X$.*

Clearly, whether externalities are tackled via taxation or a true price has distributional consequences. This is obvious, as the (voluntary) TP offers an opt out for consumers who find it too costly too prevent or compensate the TP. Instead, consumers who are willing to pay for the externality prefer taxation. Note that, in *this* model, it is not because they want other people to pay their fair share. The reason is more prosaic. A tax decreases demand from the other type and thus the price.

### 6.3 Welfare Comparison: TP vs taxation.

Now compare welfare in the two systems. An analytical comparison is not tractable, as the expressions become too complex. Instead, we use numerical simulations to provide insight and intuition. The main insight is that neither option always outperforms the other system, as Figure 1 illustrates.

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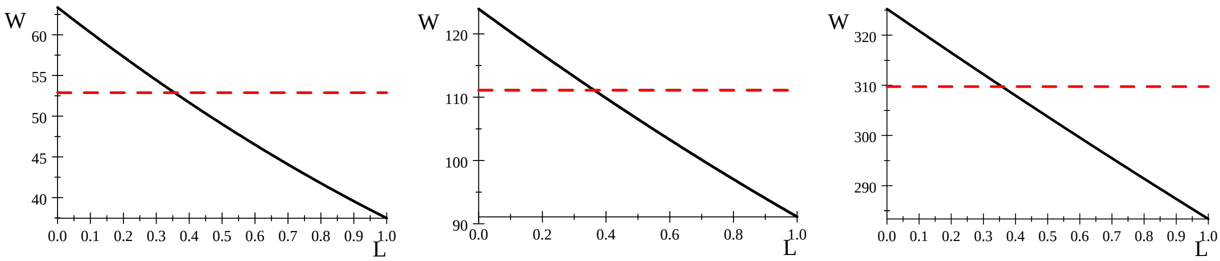

(a) $d = 0.5$ (b) $d = 1$ (c) $d = 1.5$

Figure 1. Social welfare as function of L. Parameters: $a = 12$; $b = 2$; $c = 0$; $\alpha = 0.25$; $H = 1.2$; and $X = 2$. $W^{tax}$: Red dashed line; $W^{TP2}$: Black solid line.

This figure show several simulations where for large $L$ taxation is to be preferred, whereas for low $L$ a voluntary TP is preferred. This makes sense when we see it as the result of two mechanisms.

First, taxation prevents (or compensates) all externalities, whereas under a voluntary TP type L consumers will still cause externalities. The net social benefit of preventing an externality is $LX$. The lower $L$ is, the less it matters whether the externality is prevented, so the more attractive the TP option is. As $L$ increases, it becomes increasingly important to prevent all externalities, which is what the taxation option does. This mechanism offers a reason why TP can be *relatively attractive* for low $L$, as is suggested by the figures. However, by itself it does not offer a reason why TP can be *better*.

The second mechanism offers this explation. In our model, there is market power. External effects lead to overconsumption, while market power leads to underconsumption. It is possible that these two effect neutralize each other, so that type $L$ consumers would consume the optimal quantity. If $L = 0$, any tax would then result in a suboptimal quantity being consumed by type $L$ consumers, and by that reduce welfare. In other words, given the market power, a tax equal to the externality $X$ will result in a too large reduction of consumption. As a result, a TP can be the better option. This intuition is similar to earlier literature by e.g. Buchanan (1969).

**Proposition 6** *Consider the equilibria of the tax game and the TP2 game. For some parameters, social welfare in the tax game is strictly higher than social welfare in the TP2 game. Also, for some parameters, social welfare in the tax game is strictly lower than in the TP2 game.*

As the discussion above suggests, outcomes differ because of the type L consumers. If there are no type L consumers, all consumers will pay $X$ more than the base price and cause no externalities. As a result, equilibrium demand and prices would be the same. As neither TP nor taxation would result in externalities, also welfare would be the same. This is illustrated by the simulations presented in Figure 2. There we see how welfare changes in $\alpha$, the share of type $H$ consumers. Welfare under taxation and TP are the same for $\alpha = 1$.

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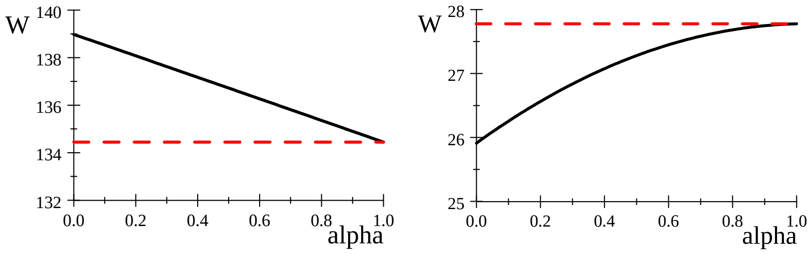


(a) $X = 1$ (b) $X = 7$

Figure 2. Social welfare as function of $\alpha$. Parameters: $a = 12$; $b = 2$; $c = 0$; $d = 1$; $L = 0.2$; and $H = 1.2$. $W^{tax}$: Red dashed line; $W^{TP2}$: Black solid line.

Figure 2 shows that $W^{tax}$ does not depend on $\alpha$. This is because under taxation, type $H$ and type $L$ face the same effective price, while neither causes an externality. It also shows that $W^{TP2}$ can decrease in $\alpha$ (Figure 2.a with $X = 1$), but also that it can increase in $\alpha$ (Figure 2.b with $X = 7$). This depends on whether H consumers generate a higher welfare or L consumers. Under true pricing we see two effects. On the one hand $L$ consumers derive more utility from the market. On the other hand $L$ consumers generate externalities, which are worse if $X$ is higher.

In a related observation we see, consistent with Figure 1, that TP is superior to taxation if the externality is low and inferior if the externality is high. This fits well with the first mechanism described above: if $X$ is low, $TP$ is relatively attractive because the externalities matter less. However, the second mechanism seems to suggest the opposite effect: the smaller $X$ is, the less likely it is that consumption is reduced to such a degree that it is harmful. Apparently the first mechanism is stronger. There is an additional mechanism here, which makes this outcome more likely. An increase in $X$ not only increases the tax, but also reduces the optimal base price and thus market power. As market power is necessary for the second mechanism, the second mechanism becomes less severe when market power decreases.

This suggest that the effects of $X$ on the comparison of taxation and TP is not straightforward. Figure 3 presents how welfare changes with $X$ for three different levels of $L$.

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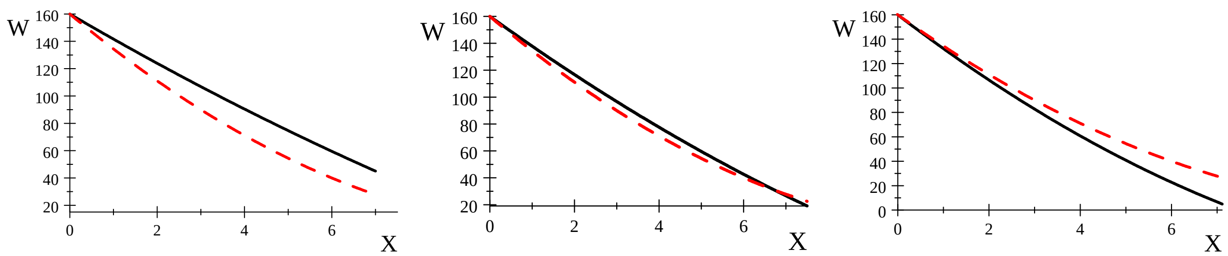


(a) $L = 0$ (b) $L = 0.2$ (c) $L = 0.5$

Figure 3. Social welfare as function of $X$. Parameters: $a = 12$; $b = 2$; $c = 0$; $d = 1$; $\alpha = 0.25$; and $H = 1.2$. $W^{tax}$: Red dashed line; $W^{TP2}$: Black solid line.

In line with the earlier simulations, Figure 3 suggests that TP2 is especially attractive if $L$ is low and especially unattractive if $L$ is high. Interesting is also Figure 3b where welfare is the same if $X = 0$, where true pricing is better if $X$ is between 0 and (roughly) 6.7, and where taxation is better if $X$ is even larger.

All in all, simulations show us that it depends on the parameters which system is better. Note that the welfare under taxation is suboptimal only because it does not correct for market power. If instead the government could tax optimally, we expect that welfare would always be higher than under voluntary universal TP.

However, we do not consider that a realistic option. The effort needed for a government to establish not only the externality of each product, but also the optimal correction for market power would be heroic. Even if it could be done, the costs of implementation would need to be taken into account, as well as the costs of litigation whenever the stakes are high enough. For companies it is easier to calculate true prices since they have detailed information on the production chain. So in real life true prices may be better than our model suggests.

This is, of course, a more general point. Our results are working within the context of our model, which (like all models) involves assumptions to make it tractable and interpretable. There are several other considerations that may make taxation or true prices more or less attractive. First, true prices only work if consumers find them credible. If the expected reduction in externalities due to the payment of 1 Euro more is only $\sigma$, $\sigma \in (0,1)$, then only consumers with $\omega > \frac{1}{\sigma}$ are willing to pay the TP. Credibility is therefore key for firms that want to implement the TP.

There is a more subtle difference between taxation and true pricing that our simplified model ignores. A tax would presumably cover all products, rather than a subset of products selected by firms. Therefore a tax that reflects the externality of each product would incentivize both firms and consumers to shift to greener alternatives.[9] A true price strategy could incentivize firms to keep less green products on the market, as it could use those products to second degree price discriminate (even more) between consumers.

Moreover it matters whether the proceeds of the TP or taxation are used to counter the externalities now (as per our model) or in the future. Both taxation and TP increase demand from H type consumers. If the proceeds are used to make future consumption greener, then TP has the net effect of increasing consumption and externalities in the short run. Taxation does not, or does so to a smaller extent, because the tax also affects $L$ type consumers directly, who will reduce their consumption by more. Therefore, the distinction between short run and long run measures may affect whether true price is to be prefered.

There are many other more realistic settings that colour the merits or demerits of true prices compared to taxes. Without wanting to overclaim things, we mention a few of them, realising that this may open a can of worms that we happily leave for future research.

The difference between taxes and true price becomes more exciting when we introduce various psychological effects in the equation. A first question is how seriously we have to take the preference of L types. There is a difference whether a $\omega$ reflects preferences (does the consumer care about income of subsistence level farmers) which are by definition subjective, or a lack of knowledge ('climate change is a hoax') which is a more objective question. In the latter case, consumers may underestimate (or overestimate) their need for greener alternatives. In the former case, TP has the advantage of tailoring to consumer heterogeneity. In the latter case, TP has the disadvantage of tailoring to a lack of knowledge.

A second fascinating psychological effect occurs if we look at the difference between voluntary (true price) and mandatory (tax). It is known from the psychological literature that people who care for external effects obtain a warm glow if they voluntary make the conscious choice of paying for it. This warm glow evaporates if the payment is mandatory through a tax. Curiously, if this warm glow is substantial it challenges the comparison result between taxes and true prices. Remember that taxes do well if L is high. But this tax advantage drops by reducing warm glow. Hence the true prices become the winner more often if warm glow enters the equation.

# 7 Conclusion

In a simple model of price competition between differentiated firms we study how true pricing affects price competition, sustainability outcomes, and welfare. True pricing, understood as firms giving consumers the normal price or that price increased with the true external costs to society, caters better to the preferences of consumers that care relatively much for sustainability outcomes. Profit-maximizing firms turn this increased demand for their services into profit by increasing their normal price. Consumers that do not pay true prices thus also pay a higher price. In other words, true pricing, even if voluntary, has distributional consequences.

It may be optimal for firms to pay part of the true price themselves, because it allows them to price discriminate more. However, doing so raises their marginal costs on all their TP sales. Therefore this is too costly if the relative increase in demand is small.

[9] Note that this is only true insofar the tax reflects the externalities of a particular product. Of course, if a tax is based on the average externality of a group of products, then typically there are no incentives to shift towards greener alternatives within that group of products.

We conduct a stylized comparison between true pricing and a government imposed tax equal to the externality. Where a true price offers consumers an opt out, taxation prevents all externalities because it is mandatory. Consequently taxation has stronger distributional consequences than true pricing. We find that either mechanism, can be better. Whether the taxation is better depends partly on the market power, because then the tax is too large resulting in a needlessly large deadweight loss. It also depends on the preferences of consumers who opt out. The more they dislike causing the externality, the less they mind being forced to pay the tax.

We have made a number of simplifying assumptions along the way. Naturally our paper does not paint the full picture of true pricing. There are limitations to our analysis. Academics may consider these avenues for future research. Practitioners such as firms, policymakers, and supervisory authorities may benefit from the following considerations when designing or evaluating true pricing. First, consumers are assumed to know the size of the externality, which means that the model abstracts from the possibility that true pricing informs consumers of the sustainability level of their choices. One possible pathway for true pricing to contribute to sustainability is precisely to inform consumers about (the size of) externalities. Demand for the product in question may increase or decrease, depending on the belief consumers hold before they see the true price (which may be optimistic as well as pessimistic relative to the true externality).[10]

Consumers may also use true price information to choose products that are more sustainable. A second limitation of our model is that it ignores this mechanism as consumers can buy only one product of a given sustainability level. Third, we assume that the proceeds from true pricing are used to completely remove the externality. This is a strong assumption as it essentially presupposes that firms have access to some sustainable technology. It depends on the circumstances of a particular case whether or not such a technology is available. For example, proceeds from true pricing may be relatively easily used to pay fair wages to farmers. Indeed, this explains the existence of fair trade products. Carbon free aviation, however, is currently unavailable. From a descriptive standpoint, one may of think of this assumption as a limit on the practical relevance of our results to cases where externalities indeed can be prevented or compensated. From a policy standpoint, the assumption highlights the fact that if true pricing is to bring about sustainability benefits beyond those from more transparency, the proceeds must be actually used to improve sustainability.

Finally, we assume that firms are purely interested in profits. Our model shows that profit-maximizing firms may find it optimal to engage in true pricing, and sometimes even prefer to pay part of the true price themselves. Firms may also care about the environment. Conceivably, firms with social preferences would engage in true pricing more often, and be more willing to pay part of the true price. It is not clear whether firms with social preferences are less likely impose negative distributional consequences on consumers with a low willingness to pay for the environment. After all, firms with social preferences attach some disutility from unsustainable consumption.

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[10] Another variant of the true price is where consumers cannot opt out. Note that Section 6.1 can also be interpreted as the case with non-voluntary true pricing, as a mandatory payment of the TP is equivalent to a tax.

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# A Proofs

**Proof of Lemma 1**
**Proof.** The first order condition $\frac{\partial}{\partial p_i}\pi_i(\cdot) = 0$ yields

$$2bp_i = a + bc - (b-d)\,\bar{\omega}X + dp_j.$$

Solving this by substitution results in

$$p_i = p_j = p^{BM} = \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d}$$

By substitution, we obtain demand and profits:

$$\begin{aligned}
D^{BM} &= D\left(p^{BM}, p^{BM}\right) \\
&= a - (b-d)\left(\tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \bar{\omega}X\right) \\
&= b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d}
\end{aligned}$$

$$\begin{aligned}
\pi^{BM} &= \left(p^{BM} - c\right) D^{BM} \\
&= \tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d}\left(b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d}\right) \\
&= b\left(b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d}\right)^2
\end{aligned}$$

*QED* ■

**Proof of Proposition 1.**
**Proof.** The profit functions are

$$\begin{aligned}
\pi_A^{TPA}(p_A, p_B) &= (p_A - c)\left(a - bp_A + dp_B - (b-d)\,\bar{\omega}X + b\alpha\,(H-1)\,X\right) \\
\pi_B^{TPA}(p_A, p_B) &= (p_B - c)\left(a - bp_B + dp_A - (b-d)\,\bar{\omega}X - d\alpha\,(H-1)\,X\right)
\end{aligned}$$

The first order conditions of each firm with respect to their own price result in:

$$\begin{aligned} 2bp_A &= a + bc + dp_B - (b-d)\bar{\omega}X + b\alpha(H-1)X, \\ 2bp_B &= a + bc + dp_A - (b-d)\bar{\omega}X - d\alpha(H-1)X. \end{aligned}$$

By substitution we obtain:

$$\begin{aligned} 2bp_A &= \tfrac{2b+d}{2b}\left(a + bc - (b-d)\bar{\omega}X\right) + \tfrac{2b^2-d^2}{2b}\alpha(H-1)X + \tfrac{d^2}{2b}p_A \\ \tfrac{4b^2-d^2}{2b}p_A &= \tfrac{2b+d}{2b}\left(a + bc - (b-d)\bar{\omega}X\right) + \tfrac{2b^2-d^2}{2b}\alpha(H-1)X \\ p_A^{TPA} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X \\ &= p^{BM} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X. \end{aligned}$$

Similarly

$$\begin{aligned} p_B^{TPA} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X \\ &= p^{BM} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X. \end{aligned}$$

By substitution we obtain demand:

$$\begin{aligned} D_A^{TPA}\left(p_A^{TPA}, p_B^{TPA}\right) &= a - bp_A + dp_B - (b-d)\bar{\omega}X + b\alpha(H-1)X \\ &= a - (b-d)\left(p^{BM} + \bar{\omega}X\right) - b\tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X \\ &\quad - d\tfrac{db}{4b^2-d^2}\alpha(H-1)X + b\alpha(H-1)X \\ &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right) \\ &= b\left(\tfrac{D^{BM}}{b} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right) \end{aligned}$$

Similarly

$$D_B^{TPA}\left(p_B^{TPA}, p_A^{TPA}\right) = b\left(\tfrac{D^{BM}}{b} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X\right)$$

Lastly, noting that $p_i^{TPA} - c = \frac{D_i^{TPA}}{b}$, we obtain

$$\begin{aligned} \pi_A^{TPA}\left(p_A^{TPA}, p_B^{TPA}\right) &= b\left(\tfrac{D^{BM}}{b} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right)^2 \\ \pi_B^{TPA}\left(p_B^{TPA}, p_A^{TPA}\right) &= b\left(\tfrac{D^{BM}}{b} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X\right)^2 \end{aligned}$$

*QED* ■

**Proof of Proposition 2**

**Proof.** Consider first total profits.

$$\begin{aligned} \pi_A^{TPA} + \pi_B^{TPA} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right)^2 \\ &\quad + b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} - \tfrac{db}{4b^2-d^2}\alpha(H-1)X\right)^2 \\ &> b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right)^2 \\ &\quad + b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} - \tfrac{2b^2-d^2}{4b^2-d^2}\alpha(H-1)X\right)^2 \\ &> 2b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d}\right)^2 = \pi_A^{BM} + \pi_B^{BM} \end{aligned}$$

The first inequality follows from $2b^2 - d^2 > db$, as $2b^2 - db - d^2 = b^2 - d^2 + b(b-d)$ which is positive by $b > d > 0$. The second inequality is a standard result from mathematics: $(x+y)^2 + (x-y)^2 = 2x^2 + 2y^2 > 2x^2$.

Total demand also increases:

$$\begin{aligned}
D^{TPA}_{A+B} &= D^{TPA}_{A} + D^{TPA}_{B} \\
&= 2b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \frac{b-d}{2b-d}\alpha\left(H-1\right)X \\
&> 2b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} = D^{BM}_{A} + D^{BM}_{B}
\end{aligned}$$

Total externalities decrease. To see this, first note that demand at $B$ decreases, $D^{BM} > D^{TPA}_{B}$. Second, uncompensated demand at $A$ decreases as well because ($i$) some of the consumer who bought from $A$ in the BM case, now pay the TP; ($ii$) some consumers who do not pay the TP switch from $A$ to $B$, as $p^{TPA}_{A} > p^{BM} > p^{TPA}_{B}$, but not vice versa; and ($iii$) the consumers who neither pay the TP nor buy at $B$, are paying a higher price at $A$ than before, as $p^{TPA}_{A} > p^{BM}$. The first two observations imply that fewer people buy from $A$ without paying the TP in the TPA case than in the BM case. The last observation implies that each of those consumers purchase less than in the BM case. It follows that in the TPA case there is less uncompensated consumption at both firms.

Now consider who wins and who loses by the introduction of a TP by firm $A$. We see that this benefits firm $A$, while it harms firm $B$: $\pi^{TPA}_{A} > b\left(\frac{D^{BM}_{i}}{b}\right)^{2} = \pi^{BM} > \pi^{TPA}_{B}$. Moreover, all consumers that buy at $B$ in the BM case, can buy at $B$ at lower prices in the TPA case. Therefore all $B$-consumers benefit. The same applies to $A$-consumers of type $H$: by Eq. (3) they now pay a lower effective price.

$A$-consumers who switch to $B$, now do not buy from their prefered firm, but do pay a lower price. The net effect depends on the price decrease and the strength of their preference.

$A$-consumers who stop buying or who buy from $A$ at the standard price lose, as the price has gone up. *QED* ■

**Proof of Lemma 3**

**Proof.** The profit function of firm $i$ is given by $\pi_i\left(p_i,p_j\right) = \left(p_i - c\right)D_i\left(p_i,p_j\right).$ The first order condition with respect to its own price $p_i$ gives

$$2bp_i = a + bc - (b-d)\bar{\omega}X + \alpha\left(b-d\right)\left(H-1\right)X + dp_j.$$

This holds for both firms. By substitution we obtain $p_i = p^{TP2}$, where

$$\begin{aligned}
p^{TP2} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha\tfrac{(b-d)}{2b-d}\left(H-1\right)X \\
&= p^{BM} + \tfrac{(b-d)}{2b-d}\alpha\left(H-1\right)X
\end{aligned}$$

Substituting these equilibrium prices in the demand and profit functions gives $D_i = D^{TP2}$ and $\pi_i = \pi^{TP2}_{i}$:

$$\begin{aligned}
D^{TP2} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\tfrac{b-d}{2b-d}\left(H-1\right)X\right) \\
\pi^{TP2} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\tfrac{b-d}{2b-d}\left(H-1\right)X\right)^{2}
\end{aligned}$$

*QED* ■

**Proof of Proposition 3**

**Proof.** The proof follows immediately from the increased demand and profits and the zero cost of implementation.

*QED* ■

**Proof of Proposition 4**

**Proof.** The first bullet follows by continuity from Proposition 3. The second bullet is obvious as profits after entry are finite. Finally, the third bullet follows if we can prove that $F^{*} < F^{**}$. This is the case if $\left(\pi^{TPA}_{A} - \pi^{BM}\right) > \left(\pi^{TP2} - \pi^{TPA}_{B}\right).$

Define $Y = \frac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d}$, $Z_A = \frac{2b^2-d^2}{4b^2-d^2}\alpha\left(H-1\right)X$, $Z_B = \frac{db}{4b^2-d^2}\alpha\left(H-1\right)X$, en $Z_2 = \frac{b-d}{2b-d}\alpha\left(H-1\right)X$.

$$\begin{aligned}
\pi^{TPA}_{A} - \pi^{BM} &= bZ_A\left(2Y + Z_A\right) \\
\pi^{TP2} - \pi^{TPA}_{B} &= bZ_2\left(2Y + Z_2\right) + bZ_B\left(2Y - Z_B\right) \\
&= b\left(Z_2 + Z_B\right)\left(2Y\right) + b\left(Z_2 - Z_B\right)\left(Z_2 + Z_B\right) \\
&= b\left(Z_2 + Z_B\right)\left(2Y + Z_2 - Z_B\right)
\end{aligned}$$

So

$$\begin{aligned}
\pi_A^{TPA} - \pi^{BM} &> \pi^{TP2} - \pi_B^{TPA} \\
bZ_A\left(2Y + Z_A\right) &> b\left(Z_2 + Z_B\right)\left(2Y + Z_2 - Z_B\right) \\
2Y\left(Z_A - Z_B - Z_2\right) &> \left(Z_2\right)^2 - \left(Z_A\right)^2 - \left(Z_B\right)^2 \qquad (5)
\end{aligned}$$

Note that the left hand side from Eq. (5) equals zero, as

$$\begin{aligned}
Z_B + Z_2 &= \tfrac{\alpha(H-1)X}{4b^2-d^2}\left(db + \left(2b+d\right)\left(b-d\right)\right) \\
&= \tfrac{\alpha(H-1)X}{4b^2-d^2}\left(2b^2 - d^2\right) \\
&= Z_A
\end{aligned}$$

Moreover, as $Z_A, Z_B, Z_2 > 0$, and $Z_A = Z_B + Z_2$, it follows that

$$\left(Z_2\right)^2 - \left(Z_A\right)^2 - \left(Z_B\right)^2 < 0$$

Consequently, we obtain

$$\pi_A^{TPA} - \pi^X > \pi_i^{TP} - \pi_B^{TPA}$$

*QED* ■

**Proof of Proposition 5**

**Proof. First**, we show that it is not profitable to copay so much that all consumers are willing to pay the TP. Consider $\sigma \in [0, L]$. We show that this results in lower profits than with $\sigma = 1$. If $\sigma \leq L$ all consumers who buy at $A$ will pay the TP, as $\sigma X \leq LX$.

Demand is then equal to

$$\begin{aligned}
D_A^{\sigma\leq L}\left(p_A, p_B\right) &= a - b\left(p_A + \sigma X\right) + \alpha d\left(p_B + \bar{\omega}X\right) \\
&= a - bp_A + dp_B - \left(b-d\right)\bar{\omega}X + \left(\bar{\omega} - \sigma\right)bX \\
D_B^{\sigma\leq L}\left(p_B, p_A\right) &= a - b\left(p_B + \bar{\omega}X\right) - d\left(p_A + \sigma X\right) \\
&= a - bp_B + dp_A - \left(b-d\right)\bar{\omega}X - \left(\bar{\omega} - \sigma\right)dX
\end{aligned}$$

Profits become

$$\begin{aligned}
\pi_A^{\sigma\leq L}\left(p_A, p_B\right) &= \left(p_A - c - \left(1-\sigma\right)X\right)\left(a - bp_A + dp_B - \left(b-d\right)\bar{\omega}X + \left(\bar{\omega} - \sigma\right)bX\right) \\
\pi_B^{\sigma\leq L}\left(p_B, p_A\right) &= \left(p_B - c\right)\left(a - bp_B + dp_A - \left(b-d\right)\bar{\omega}X - \left(\bar{\omega} - \sigma\right)dX\right)
\end{aligned}$$

Maximizing the profit functions, gives us the following FOCs:

$$\begin{aligned}
2bp_A &= a + bc + dp_B - \left(b-d\right)\bar{\omega}X + b\left(1-\sigma\right)X + \left(\bar{\omega} - \sigma\right)bX \\
2bp_B &= a + bc + dp_A - \left(b-d\right)\bar{\omega}X - \left(\bar{\omega} - \sigma\right)dX
\end{aligned}$$

Which results in the following equilibrium prices, demand and profits

$$\begin{aligned}
p_A^{\sigma\leq L} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \tfrac{2b^2-d^2}{4b^2-d^2}\bar{\omega}X + \tfrac{2b^2}{4b^2-d^2}X - \sigma X \\
p_B^{\sigma\leq L} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \tfrac{1-\bar{\omega}}{4b^2-d^2}bdX \\
D_A^{\sigma\leq L} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \tfrac{2b^2-d^2}{4b^2-d^2}\left(\bar{\omega} - 1\right)X\right) \\
\pi_A^{\sigma\leq L} &= b\left(\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \tfrac{2b^2-d^2}{4b^2-d^2}\left(\bar{\omega} - 1\right)X\right)^2
\end{aligned}$$

Note that $p_A^{\sigma}$ decreases by, $\sigma X$, the amount of the TP that the consumer pays herself. This means that the effective price, $p_A + \sigma X$, for the consumers at $A$ stays unchanged. Hence $D_A^{\sigma\leq L}$ and $\pi_A^{\sigma\leq L}$ are the same for all $\sigma \leq L$.

We now show that profits are strictly higher if $\sigma = 1$, so $\pi_A^{TPA} > \pi_A^{\sigma \leq L}$. If $D_A^{\sigma \leq L} \leq 0$, then $D_A^{\sigma \leq L} = \pi_A^{\sigma \leq L} = 0 < \pi_A^{TPA}$. If $D_A^{\sigma \leq L} > 0$, then

$$\begin{array}{rcl} \pi_A^{\sigma \leq L} & < & \pi_A^{TPA} \\ b\left(\frac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \frac{2b^2-d^2}{4b^2-d^2}\left(\bar{\omega}-1\right)X\right)^2 & < & b\left(\frac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \frac{2b^2-d^2}{4b^2-d^2}\alpha\left(H-1\right)X\right)^2 \\ \frac{2b^2-d^2}{4b^2-d^2}\left(\bar{\omega}-1\right)X & < & \frac{2b^2-d^2}{4b^2-d^2}\alpha\left(H-1\right)X \\ \alpha\left(H-1\right)+\left(1-\alpha\right)\left(L-1\right) & < & \alpha\left(H-1\right) \\ \left(1-\alpha\right)\left(L-1\right) & < & 0 \\ L & < & 1 \end{array}$$

which holds by assumption. It follows that $\sigma \leq L$ is not profitable.

**Second**, we consider copayments in the case that at least one type will refuse to pay the TP: $\sigma \in (L, 1]$. Then

$$\begin{array}{rcl} D_A^{\sigma > L}\left(p_A, p_B, \sigma\right) & = & a - \alpha b\left(p_A + \sigma X\right) - \left(1-\alpha\right) b\left(p_A + LX\right) + d\left(p_B + \bar{\omega}X\right) \\ & = & a - bp_A + dp_B - \left(b-d\right)\bar{\omega}X + \alpha b\left(H-\sigma\right)X \\ D_B^{\sigma > L}\left(p_B, p_A, \sigma\right) & = & a - bp_B + dp_A - \left(b-d\right)\bar{\omega}X - \alpha d\left(H-\sigma\right)X \end{array}$$

The amount $A$ sells at TP is equal to

$$D_{A,TP}^{\sigma > L}\left(p_A, p_B, \sigma\right) = \alpha\left(a - bp_A + dp_B - b\sigma X + dHX\right)$$

Profits are equal to

$$\begin{array}{rcl} \pi_A^{\sigma > L}\left(p_A, p_B\right) & = & \left(p_A - c\right) D_A^{\sigma > L} - D_{A,TP}^{\sigma > L}\left(1-\sigma\right)X \\ & = & \left(p_A - c\right)\left(a - bp_A + dp_B - \left(b-d\right)\bar{\omega}X + \alpha b\left(H-\sigma\right)X\right) \\ & & -\alpha\left(a - bp_A + dp_B - b\sigma X + dHX\right)\left(1-\sigma\right)X \\ \pi_B^{\sigma > L}\left(p_B, p_A\right) & = & \left(p_B - c\right)\left(a - bp_B + dp_A - \left(b-d\right)\bar{\omega}X - \alpha d\left(H-\sigma\right)X\right) \end{array}$$

First order conditions give

$$\begin{array}{rcl} 2bp_A & = & a + bc + dp_B - \left(b-d\right)\bar{\omega}X + \alpha b\left(H-\sigma\right)X + \alpha b\left(1-\sigma\right)X \\ 2bp_B & = & a + bc + dp_A - \left(b-d\right)\bar{\omega}X - \alpha d\left(H-\sigma\right)X \end{array}$$

As both FOCs hold simultaneously, we obtain

$$\begin{array}{rcl} p_A^{\sigma > L}\left(\sigma\right) & = & \frac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha\frac{\left(2b^2-d^2\right)}{4b^2-d^2}\left(H-\sigma\right)X + \alpha\frac{2b^2(1-\sigma)}{4b^2-d^2}X \\ p_B^{\sigma > L}\left(\sigma\right) & = & \frac{a+bc-(b-d)\bar{\omega}X}{2b-d} - \frac{bd}{4b^2-d^2}\alpha\left(H-1\right)X \end{array}$$

$$p_A^{\sigma > L}\left(\sigma\right) - c = \frac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\frac{\left(2b^2-d^2\right)}{4b^2-d^2}\left(H-\sigma\right)X + \alpha\frac{2b^2(1-\sigma)}{4b^2-d^2}X$$

By substitution, in equilibrium A will sell

$$D_A^{\sigma > L} = b\left(\frac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\frac{\left(2b^2-d^2\right)}{4b^2-d^2}\left(H-1\right)X\right)$$

of which

$$D_{A,TP}^{\sigma > L} = \alpha\left(b\frac{a-(b-d)c}{2b-d} + \frac{(b-d)^2\bar{\omega}X}{2b-d} - \left(1-\alpha\right)bX\sigma + \left(d - \frac{2b^3}{4b^2-d^2}\alpha\right)HX - \alpha b\frac{2b^2-d^2}{4b^2-d^2}X\right)$$

is sold at TP. Recall that

$$\pi_A^{\sigma > L}\left(p_A, p_B, \sigma\right) = \left(p_A^{\sigma > L} - c\right) D_A^{\sigma > L} - D_{A,TP}^{\sigma > L}\left(1-\sigma\right)X$$

Taking the first order derivative with respect to $\sigma$, we obtain

$$\tfrac{\partial}{\partial\sigma}\pi_A^{\sigma>L} = X^2\alpha\left(b\left(1-\alpha\right)+\left(b-d\right)\omega-\left(\alpha b-d\right)H-2b\left(1-\alpha\right)\sigma\right)$$

Therefore, we can solve for the optimal $\sigma$:

$$\begin{aligned} \sigma^{\sigma>L} &= \tfrac{b(1-\alpha)+(b-d)\bar{\omega}-(\alpha b-d)H}{2(1-\alpha)b} \\ &= \tfrac{b+Hd+(b-d)L}{2b} \end{aligned} \tag{6}$$

Note that this is an optimum as

$$\tfrac{\partial^2}{\partial\sigma^2}\pi_A^{\sigma>L}\left(p_A^{\sigma>L}\left(\sigma\right),p_B^{\sigma>L}\left(\sigma\right),\sigma\right) = -2\left(1-\alpha\right)b\alpha X^2 < 0$$

It follows that $\sigma^{\sigma>L} < 1$ if

$$\begin{aligned} b\left(1-\alpha\right)+\left(b-d\right)\bar{\omega}-\left(\alpha b-d\right)H &< 2\left(1-\alpha\right)b \\ b\left(1-\alpha\right)+\left(b-d\right)\left(\alpha H+\left(1-\alpha\right)L\right)-\left(\alpha b-d\right)H &< 2\left(1-\alpha\right)b \\ \left(1-\alpha\right)dH &< \left(1-\alpha\right)\left(b-\left(b-d\right)L\right) \\ H &< \tfrac{(b-(b-d)L)}{d} \end{aligned}$$

Note that the RHS is larger than 1, as $b-\left(b-d\right)x > d$ for all $x<1$, and $L<1$. So for any parameters $b,d,\alpha$ and $L$, there exists $\hat{H}=\frac{(b-(b-d)L)}{d}>1$, such that $\sigma^*<1$ if $H\in\left(1,\hat{H}\right)$ and $\sigma^*=1$ if $H\geq\hat{H}$.

Finally, we show by construction that $\sigma^{\sigma>L}>L$.

$$\begin{aligned} \sigma^* &> L \\ \tfrac{b+Hd+(b-d)L}{2b} &> L \\ b+dH+\left(b-d\right)L &> 2bL \\ & \quad b+d \\ b\left(1-\alpha\right)+\left(b-d\right)\bar{\omega}-\left(\alpha b-d\right)H &> 2\left(1-\alpha\right)bL \\ b\left(1-\alpha\right)+\left(b-d\right)\left(\alpha H+\left(1-\alpha\right)L\right)-\left(\alpha b-d\right)H &> 2\left(1-\alpha\right)bL \\ \left(1-\alpha\right)\left(b+dH-\left(b+d\right)L\right) &> 0 \end{aligned}$$

By $L<1<H$, the LHS is positive.

To summarize, there exists $\hat{H}>1$ such that for $H\in\left(1,\hat{H}\right)$ we have $\sigma^{CPA}=\sigma^{\sigma>L}\in\left(L,1\right)$, while $\sigma^{CPA}=\sigma^{\sigma>L}=1$ for $H\geq\hat{H}>1$. *QED.* ■

**Proof of Lemma 4**

**Proof.** Let $I$ be the budget of the representative consumer, and $m$ the expenditure on the numeraire good. Let the marginal utility of the numeraire good be constant and equal to 1. This results in the total utility function.

$$\tilde{U}\left(q_i,q_j\right)=\gamma\left(q_A+q_B\right)-\tfrac{\beta}{2}\left(q_A^2+2\theta q_Aq_B+q_B^2\right)+m$$

The budget constraint can be written as $m=I-p_Aq_A-p_Bq_B$. By substitution we obtain the following function to maximize:

$$\max_{q_A,q_B}\tilde{U}\left(q_A,q_B\right)=\left(\gamma\left(q_A+q_B\right)-\tfrac{\beta\left(q_A^2+2\theta q_Aq_B+q_B^2\right)}{2}+I-p_Aq_A-p_Bq_B\right).$$

For each $i\in\{A,B\}$, this results in the following FOC w.r.t. $q_i$:

$$\frac{\partial}{\partial q_i}\hat{U}\left(\cdot\right)=\gamma-\beta\left(q_i+\theta q_j\right)-p_i=0,\text{ where } j\in\{A,B\}\setminus\{i\}$$

As both FOCs need to hold, we have

$$\begin{aligned} \beta q_i &= \gamma-p_i-\beta\theta q_j \\ &= \gamma-p_i-\theta\left(\gamma-p_j-\beta\theta q_i\right) \\ \beta\left(1-\theta^2\right)q_i &= \left(1-\theta\right)\gamma-p_i+\theta p_j \end{aligned}$$

which results in

$$q_i = \frac{\gamma}{\beta(1+\theta)} - \frac{1}{\beta(1-\theta^2)} p_i + \frac{\theta}{\beta(1-\theta^2)} p_j$$

This is equivalent to the residual demand function in Eq. (1) if $a = \frac{\gamma}{\beta(1+\theta)}$, $b = \frac{1}{\beta(1-\theta^2)}$, and $d = \frac{\theta}{\beta(1-\theta^2)}$. From this it follows that $d = \theta b$, so $\theta = \frac{d}{b}$. Moreover, $b = \frac{1}{\beta(1-\theta^2)}$, implies $\beta = \frac{1}{b(1-\theta^2)} = \frac{1}{b\left(1-\frac{d^2}{b^2}\right)} = \frac{b}{2(b-d)(b+d)}$, and $\gamma = a\beta(1+\theta) = \frac{a(1+\theta)}{b(1-\theta^2)} = \frac{a}{b(1-\theta)} = \frac{a}{b\left(1-\frac{d}{b}\right)} = \frac{a}{b-d}$.

Now consider the CS generated by the duopolist's market. In a symmetrical equilibrium with $q_A = q_B = q$ and $p_A = p_B = p$, the surplus obtained from this market is given by

$$\begin{aligned} CS(q,p) &= U(q,q) - 2qp \\ &= 2\gamma q - \frac{\beta}{2}\left(2q^2 + 2\theta q^2\right) - 2qp \\ &= 2\left(\frac{a}{b-d} - p\right) q - \frac{b}{2(b-d)(b+d)}\left(1 + \frac{d}{b}\right) q^2 \\ &= 2\left(\frac{a}{b-d} - p\right) q - \frac{1}{2(b-d)} q^2 \end{aligned}$$

$CS(q,p) + 2\pi = U(q,q) - 2qp + 2q(p-c) = U(q,q) - 2qc$

In case of $y$ externalities,

$$\begin{aligned} W &= U(q,q) - 2qc - yX \\ &= 2\left(\frac{a}{b-d} - c\right) q - \frac{1}{2(b-d)} q^2 - yX \end{aligned}$$

$$U(q_i, q_j, m) = \gamma(q_A + q_B) - \frac{\beta}{2}\left(q_A^2 + 2\theta q_A q_B + q_B^2\right),$$

where $\gamma = \frac{a}{b-d}$, $\beta = \frac{b}{2(b-d)(b+d)}$, and $\theta = \frac{d}{b}$. The consumer surplus from the duopolists' market is equal to

$$CS(q,p) = 2\left(\frac{a}{b-d} - p\right) q - \frac{1}{2(b-d)} q^2 \tag{7}$$

*QED.* ■

**Proof of Lemma 5**

**Proof.** The profit function is $\pi_i(\cdot) = (p_i - c) D_i(\cdot)$. The first order condition gives

$$2bp_i^{tax} = a + bc + dp_j - (b-d) X$$

for each firm $i$. By substitution we obtain $p_i^{tax} = p_j^{tax} = p^{tax}$ where

$$\begin{aligned} p^{tax} &= \frac{a+bc-(b-d)X}{2b-d} \\ &= p^{BM} - \frac{b-d}{2b-d}(1-\bar{\omega}) X \end{aligned}$$

This results in

$$\begin{aligned} D_i^{tax}\left(p^{tax}, p^{tax}\right) &= a - (b-d) p^{tax} - (b-d) X \\ &= b\frac{a-(b-d)c-(b-d)X}{2b-d} = D^{tax} \\ \pi_i^{tax}\left(p^{tax}, p^{tax}\right) &= b\left(\frac{a-(b-d)c-(b-d)X}{2b-d}\right)^2 = \pi^{tax} \end{aligned}$$

Now we consider the social welfare. Note that the tax itself has a net contribution of 0: the benefit of the tax is equal to the amount paid. Note that Eq. (4) applies to the case without taxes. With taxes social surplus becomes

$$\begin{aligned} CS(q,p) &= U(q,q) - 2q(p+X) \\ &= 2\gamma q - \frac{\beta}{2}\left(2q^2 + 2\theta q^2\right) - 2q(p+X) \\ &= 2\left(\frac{a}{b-d} - p - X\right) q - \frac{2b\left(1+\frac{d}{b}\right)}{4(b-d)(b+d)} q^2 \\ &= 2\left(\frac{a}{b-d} - p - X\right) q - \frac{1}{2(b-d)} q^2 \end{aligned}$$

Social welfare is thus equal to

$$\begin{aligned}
W^{tax} &= CS^{tax} + PS^{tax} \\
&= CS^{tax} + 2\pi^{tax} \\
&= 2\left(\tfrac{a}{b-d} - p^{tax} - X\right) D^{tax} - \tfrac{1}{2(b-d)}\left(D^{tax}\right)^2 + 2\left(p^{tax} - c\right) D^{tax} \\
&= 2\left(\tfrac{a-(b-d)c-(b-d)X}{b-d}\right) D^{tax} - \tfrac{1}{2(b-d)}\left(D^{tax}\right)^2 \\
&= \left(2\tfrac{a-(b-d)c-(b-d)X}{b-d} - \tfrac{1}{2(b-d)} D^{tax}\right) D^{tax}
\end{aligned}$$

Finally we show that $p^{BM} + LX < p^{tax} + X < p^{BM} + HX$. Consider a consumer $k$ with $\omega_k$. Then

$$\begin{aligned}
p^{BM} + \omega_k X &> p^{tax} + X \\
\tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \omega_k X &> \tfrac{a+bc-(b-d)X}{2b-d} + X \\
(2b-d)\,\omega_k X - (b-d)\,\bar{\omega} X &> (2b-d)\,X - (b-d)\,X \\
(2b-d)\,(\omega_k - 1) &> (b-d)\,(\bar{\omega} - 1) \\
b\,(\omega_k - 1) &> (b-d)\,(\bar{\omega} - \omega_k)
\end{aligned}$$

This holds only if $\omega_k = H$. Then the LHS is positive as $H > 1$, while the RHS is negative ($\bar{\omega} < H$). If instead $\omega_k = L$, then the LHS is negative, $L < 1$, whereas the RHS is positive, $L < \bar{\omega}$. As a result $p^{BM} + LX < p^{tax} + X < p^{BM} + HX$. *QED.* ■

**Proof of Lemma 6**

**Proof.** To derive $W^{TP2}$, observe that any externalities come from consumers with $\omega = L$, which is share $(1-\alpha)$ of the consumers. The remaining consumers pay the TP, and therefore pay a higher price, $p^{TP2} + X$. We therefore need to know how much is sold to which group. Firm $i$ sells $D_i^{\omega=L}$ to consumers with $\omega = L$, where $D_i^{\omega=L} = (1-\alpha)\,D^L$, and

$$\begin{aligned}
D^L &= a - (b-d)\,p^{TP2} - (b-d)\,LX \\
&= a - (b-d)\left(\tfrac{a+bc-(b-d)(\alpha H+(1-\alpha)L)X}{2b-d} + \tfrac{(b-d)}{2b-d}\alpha\,(H-1)\,X\right) - (b-d)\,LX \\
&= b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha\tfrac{b-d}{2b-d}\left((b-d)\,(1-L) + b\,(H-L)\right) X \\
&= D^{TP2} + \alpha\,(1-L)\,(b-d)\,X \\
D_i^{\omega=L} &= (1-\alpha)\left(D^{TP2} + \alpha\,(1-L)\,(b-d)\,X\right)
\end{aligned}$$

**Proof.** The amount sold to consumers with $\omega = H$ is therefore equal to

$$\begin{aligned}
D_i^{\omega=H} &= D^{TP2} - D_i^{\omega=L} \\
&= D^{TP2} - (1-\alpha)\left(D^{TP2} + \alpha\,(1-L)\,(b-d)\,X\right) \\
&= \alpha\left(D^{TP2} - (1-\alpha)\,(1-L)\,(b-d)\,X\right)
\end{aligned}$$

Then welfare is equal to

$$\begin{aligned}
W^{TP2} &= 2\left(\tfrac{a}{b-d} - c\right) D^{TP2} - \tfrac{1}{2(b-d)}\left(D^{TP2}\right)^2 - 2\alpha\left(D^{TP2} - (1-\alpha)\,(1-L)\,(b-d)\,X\right) X \\
&\quad -2\,(1-\alpha)\left(D^{TP2} + \alpha\,(1-L)\,(b-d)\,X\right)(1+L)\,X \\
&= 2\left(\tfrac{a-(b-d)c}{b-d}\right) D^{TP2} - \tfrac{1}{2(b-d)}\left(D^{TP2}\right)^2 - 2\,(1+(1-\alpha)\,L)\,D^{TP2}X \\
&\quad -2\alpha\,(1-\alpha)\,(b-d)\,(1-L)\,LX^2
\end{aligned}$$

■

*QED* ■

**Proof of Proposition 6**

We prove this by example. Let $a = 12$, $b = 2$, $c = 0$, $d = 1$, $\alpha = 0.25$, $H = 1.2$ and $X = 2$. If $L = 0.2$ then $W^{TP2} \approx 117$ and $W^{tax} \approx 111$, so $W^{TP2} > W^{tax}$. If instead $L = 0.8$, then $W^{TP2} \approx 97$ and $W^{tax} \approx 111$, so $W^{TP2} < W^{tax}$.

**Proof.** *QED* ■

# B Parameter conditions

In this section we derive the upper bounds on $X$ such that, in each of the equilibria, both firms face positive demand from each type of consumer. The result is as follows.

**Lemma 7** *Consider the TP game. Then for each of the equilibria, both firms face positive demand from both types of consumers if the following conditions hold:*

$$a > (b-d)(c+\bar{\omega}X) \tag{8}$$
$$X < \frac{b(a-(b-d)c)}{(b-d)((2b-d)H-(b-d)\bar{\omega})} \tag{9}$$

$$\begin{cases} Y<0 & or \\ Y>0 & and \quad X \leq \frac{2b(2b+d)(a-(b-d)c)}{Y} \end{cases}, \text{ where} \tag{10}$$
$$\begin{aligned} Y &= 2b(b-d)(2b+d)L - \\ &\quad \alpha\left(\left(2(b-d)\left(4b^2-d^2\right)-(2b-d)d^2\right)H-(b-d)\left(6b^2-2bd-3d^2\right)L-b\left(2b^2-3d^2\right)\right) \end{aligned}$$

$$\begin{cases} Z<0 & or \\ Z>0 & and \quad X < \frac{2b^2(2b+d)(a-(b-d)c)}{Z} \end{cases}, \text{ where} \tag{11}$$
$$\begin{aligned} Z &= 2b^2\left(4b^2-d^2\right)H-2b^3(2b+d)L-2bd\left(4b^2-d^2\right) \\ &\quad -\alpha\left(\left(\left(4b^2-d^2\right)(2b+d)d+4b^4\right)H-\left(2b^3(2b+d)-d(b-d)\left(4b^2-d^2\right)\right)L-bd\left(2b^2-d^2\right)\right) \end{aligned}$$

*There exists a range of parameters for which all these conditions are satisfied.*

**Proof.** See Lemma's 8, 9 and 10 below for the conditions. We now show that there exists a range of parameters that for which all these conditions are satisfied. We show this by example. The range follows, by continuity, from the strict inequalities. In particular, let $c=L=0$, and let $\alpha$ approach 0 (so $\bar{\omega}$ approaches 0) then for any $a>0$ condition (8) is satisfied. Let $H=\frac{5}{4}$, $b=2$ and $d=1$. Then for $a=60$, Condition (9) requires

$$X < \frac{120}{(3H)} = \frac{120}{\left(\frac{15}{4}\right)} = \frac{480}{15} = 32$$

Now consider Condition (10). $Y=\frac{95}{4}\alpha>0$. Condition simplifies to

$$X \leq \frac{80a}{95\alpha}$$

As $\alpha$ approaches 0, this condition is trivially satisfied for any finite $X$.

Finally, consider condition (11). For the given parameters, $Z=90-\frac{639}{4}\alpha=90$. The relevant condition is therefore $X<\frac{8(5)(60)}{90}=\frac{80}{3}$.

Combined, for the given parameters, $X<\frac{80}{3}$ is sufficient to guarantee positive demand from each type of consumer for each firm, in all of the equilibria. ■

## B.1 Symmetric TP policy

**Lemma 8** *Consider the TP game. If neither or both firms offer the TP then both firms face positive demand from both sides if and only if $X<X^{BM}$, where $X^{BM}=\frac{b(a-(b-d)c)}{(b-d)((2b-d)H-(b-d)\bar{\omega})}$.*

**Proof.** If neither firm offers a TP, then type $H$ has the lowest demand. Equilibrium demand from type $H$ at store $i$ equals $D_i^{BM,H}$, where

$$D_i^{BM,H}\left(p^{BM},p^{BM}\right)=\alpha\left(a-(b-d)\left(p^{BM}+HX\right)\right)$$

This is positive if

$$\begin{aligned} a &> (b-d)\left(\frac{a+bc-(b-d)\bar{\omega}X}{2b-d}+HX\right) \\ ba-(b-d)bc &> (b-d)(2b-d)HX-(b-d)^2\bar{\omega}X \end{aligned}$$

where the RHS is positive as $H > \bar{\omega}$ and $(2b-d) > (b-d)$. So we obtain positive demand if

$$X < X^{BM} = \frac{b(a-(b-d)c)}{(b-d)((2b-d)H-(b-d)\bar{\omega})}$$

By $a > (b-d)(c+\bar{\omega}X)$ and $b > d > 0$ and $H > \bar{\omega}$, we have $X^{BM} > 0$. It follows that $X$ can and must be small enough.

If both firms offer a TP, so both firms charge $p^{TP2}$, then still type $H$ pays the highest effective price: $p^{TP2} + LX < p^{TP2} + X$. However, this effective price is lower than in case neither firm offers a TP:

$$\begin{aligned} p^{TP2} + X &= p^{BM} + \tfrac{(b-d)}{2b-d}\alpha (H-1) X + X \\ &< p^{BM} + (H-1) X + X \\ &= p^{BM} + HX \end{aligned}$$

So the upper bound for the BM case is sufficient for TP2 as well. ■

## B.2 One firm offers the TP

Suppose instead that only one firm, say firm A, offers the TP. Then prices are asymmetric. Firm $A$ may face zero demand from type $L$, as firm $B$ offers them a lower (effective) price. Likewise, firm $B$ may face zero demand from type $H$ consumers, as $A$ offers a lower effective price to type $H$. Recall that

$$\begin{aligned} p_A^{\sigma<1}(\sigma) &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2}(H-\sigma) X + \alpha \tfrac{2b^2(1-\sigma)}{4b^2-d^2} X \\ p_B^{\sigma<1}(\sigma) &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} - \tfrac{bd}{4b^2-d^2}\alpha (H-1) X \end{aligned}$$

There are two candidate values for $\sigma$, $\sigma = 1$ and $\sigma = \sigma^{\sigma<1} = \frac{b(1-\alpha)+(b-d)\bar{\omega}-(\alpha b-d)H}{2(1-\alpha)b} = \frac{b+Hd+(b-d)L}{2b}$. Note that $\sigma < 1$ requires that $H < \hat{H} = \frac{(b-(b-d)L)}{d}$.

$$\begin{aligned} p_A^{\sigma=1} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2}(H-1) X \\ p_A^{\sigma<L} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} HX - \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2}\sigma X + \alpha \tfrac{2b^2(1-\sigma)}{4b^2-d^2} X \\ &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} HX - \alpha \left( \tfrac{(b-d)L+dH}{2b} - \tfrac{d^2}{2(4b^2-d^2)} \right) X \\ &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} HX - \alpha \left(2b^2-d^2\right) \tfrac{b+dH+(b-d)L}{2b(4b^2-d^2)} X \\ &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} - \alpha \left(2b^2-d^2\right) \tfrac{b-(2b-d)H+(b-d)L}{2b(4b^2-d^2)} X \\ p_B^{\sigma=1} &= p_B^{\sigma<L} = p_B^{\sigma} = \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} - \alpha \tfrac{bd}{4b^2-d^2}(H-1) X \end{aligned}$$

For comparing type $L$ this is enough, as they do not pay the TP at either firm. Note that for consumers of type $H$ the effective price at firm $A$ is lower in the case of copayments, $\sigma < 1$, than in the case without copayments, $\sigma = 1$.

$$\begin{aligned} p_A^{\sigma=1} + X &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2}(H-1) X + X && (12) \\ p_A^{\sigma<L} + \sigma X &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2}(H-\sigma) X + \alpha \tfrac{2b^2(1-\sigma)}{4b^2-d^2} X + \sigma X && (13) \\ &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} HX + \alpha \tfrac{2b^2}{4b^2-d^2} X - \sigma\alpha \tfrac{2b^2}{4b^2-d^2} X - \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2}\sigma X + \sigma X \\ &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} HX + \alpha \tfrac{2b^2}{4b^2-d^2} X + (1-\alpha)\sigma X && (14) \\ &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} HX + \alpha \tfrac{2b^2}{4b^2-d^2} X + (1-\alpha) \tfrac{b-Hd-(b-d)L}{2b} X \end{aligned}$$

Looking at Eqs (12) and (13) we see that they are indeed the same for $\sigma = 1$. Eq (12) can be rewritten as Eq (14), which shows that the lower $\sigma$ is, the lower the effective price for type $H$ at firm $A$. Consequently, if there is positive demand for firm $B$ from type $H$ under copayment, this demand is also positive without copayment.

### B.2.1 Demand from type $H$ at firm $B$

The effective price of $A$ to type $H$ is equal to $p_A + \sigma X$. This is lowest if $\sigma < L$. The effective price to type $H$ at $B$ does not depend on $\sigma$. Therefore demand is lowest if $\sigma < 1$, so $\sigma = \frac{b+Hd+(b-d)L}{2b}$.

$\bar{\omega} = \alpha H + (1-\alpha) L$

Demand for firm $B$ from type $H$ is

$$\begin{aligned}
D_B^{TPA,H,\sigma<1} &= \alpha \left(a - b\left(p_B^{\sigma} + \bar{\omega} X\right) + d\left(p_A^{\sigma<L} + \bar{\omega} X\right) - b\left(H - \bar{\omega}\right) X - d\left(\bar{\omega} - \sigma\right) X\right) \\
&= \alpha \left(a - b\left(p^{BM} - \alpha \tfrac{bd}{4b^2-d^2}\left(H-1\right) X + \bar{\omega} X\right) - b\left(H - \bar{\omega}\right) X\right) + \\
&\quad \alpha \left(d\left(p^{BM} + \alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} H X + \alpha \tfrac{2b^2}{4b^2-d^2} X + \left(1-\alpha\right) \tfrac{b-Hd-(b-d)L}{2b} X + \bar{\omega} X\right) - d\left(\bar{\omega} - \sigma\right) X\right) \\
&= \alpha \left(b \tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + b\alpha \tfrac{bd}{4b^2-d^2}\left(H-1\right) X - b\left(H - \bar{\omega}\right) X\right) + \\
&\quad \alpha \left(d\left(\alpha \tfrac{\left(2b^2-d^2\right)}{4b^2-d^2} H X + \alpha \tfrac{2b^2}{4b^2-d^2} X + \left(1-\alpha\right) \tfrac{b-Hd-(b-d)L}{2b} X + \bar{\omega} X\right) - d\left(\bar{\omega} - \sigma\right) X\right) \\
&= \alpha b \tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} + \alpha \tfrac{bd\left(2\left(4b^2-d^2\right) - \left(2b^2-d^2\right)\alpha\right)}{2b(4b^2-d^2)} X \\
&\quad + \alpha \tfrac{\left(\alpha\left(4b^2-d^2\right)\left(2b^2+d^2\right)(H-L) + \alpha bd\left(4b^2-d^2\right)(2H+L) - 2\alpha b^3 dH - 2b^2\left(4b^2-d^2\right)(H-L)\right)}{2b(4b^2-d^2)} X
\end{aligned}$$

$$\begin{aligned}
&= \alpha b \tfrac{a-(b-d)c}{2b-d} - \alpha \left(\tfrac{2\alpha b^2(b-d)(2b+d)(H-L) + 2b^2(b-d)(2b+d)L}{2b(2b-d)(2b+d)} X\right) \\
&\quad + \alpha \left(\tfrac{\left(\alpha\left(4b^2-d^2\right)\left(2b^2+d^2\right)(H-L) + \alpha bd\left(4b^2-d^2\right)(2H+L) - 2\alpha b^3 dH - 2b^2\left(4b^2-d^2\right)(H-L) + bd\left(2\left(4b^2-d^2\right) - \left(2b^2-d^2\right)\alpha\right)\right)}{2b(2b-d)(2b+d)} X\right) \\
&= \alpha b \tfrac{a-(b-d)c}{2b-d} - \alpha \left(\tfrac{\left(2b^2\left(4b^2-d^2\right) - \left(\left(4b^2-d^2\right)(2b+d)d + 4b^4\right)\alpha\right) H}{2b(2b-d)(2b+d)} X\right) \\
&\quad - \alpha \left(\tfrac{\left(\left(2b^3(2b+d) - d(b-d)\left(4b^2-d^2\right)\right)\alpha - 2b^3(2b+d)\right) L + \left(\alpha bd\left(2b^2-d^2\right) - 2bd\left(4b^2-d^2\right)\right)}{2b(2b-d)(2b+d)} X\right) \\
&= \alpha b \tfrac{a-(b-d)c}{2b-d} - \alpha \left(\tfrac{\left(4b^2-d^2\right)\left(\left(2b^2 - \alpha(2b+d)d\right) H - (d(b-d))\alpha L - 2bd\right) - 4b^4 \alpha H - (1-\alpha) 2b^3 (2b+d) L + \alpha bd\left(2b^2-d^2\right)}{2b(2b-d)(2b+d)} X\right) \\
&= \alpha b \tfrac{a-(b-d)c}{2b-d} - \alpha \left(\tfrac{2b^2\left(4b^2-d^2\right) H - 2b^3(2b+d) L - 2bd\left(4b^2-d^2\right)}{2b(4b^2-d^2)}\right) X \\
&\quad + \alpha \left(\tfrac{\alpha\left(\left(\left(4b^2-d^2\right)(2b+d)d + 4b^4\right) H - \left(2b^3(2b+d) - d(b-d)\left(4b^2-d^2\right)\right) L - bd\left(2b^2-d^2\right)\right)}{2b(4b^2-d^2)}\right) X
\end{aligned}$$

Demand is positive if

$$\begin{aligned}
& b\left(a - \left(b-d\right) c\right) \\
& > \qquad\qquad (15) \\
& \left(\tfrac{2b^2\left(4b^2-d^2\right) H - 2b^3(2b+d) L - 2bd\left(4b^2-d^2\right) - \alpha\left(\left(\left(4b^2-d^2\right)(2b+d)d + 4b^4\right) H - \left(2b^3(2b+d) - d(b-d)\left(4b^2-d^2\right)\right) L - bd\left(2b^2-d^2\right)\right)}{2b(2b+d)}\right) X
\end{aligned}$$

If the RHS is negative, than this is satisfied trivially. If the RHS is positive, then we obtain the condition that

$$X < \tfrac{2b(2b+d)b(a-(b-d)c)}{2b^2(4b^2-d^2)H - 2b^3(2b+d)L - 2bd(4b^2-d^2) - \alpha(((4b^2-d^2)(2b+d)d + 4b^4)H - (2b^3(2b+d) - d(b-d)(4b^2-d^2))L - bd(2b^2-d^2))}$$

**Lemma 9** *Let*

$$\begin{aligned}
Z &= 2b^2\left(4b^2 - d^2\right) H - 2b^3\left(2b + d\right) L - 2bd\left(4b^2 - d^2\right) \\
&\quad - \alpha\left(\left(\left(4b^2 - d^2\right)\left(2b + d\right) d + 4b^4\right) H - \left(2b^3\left(2b + d\right) - d\left(b - d\right)\left(4b^2 - d^2\right)\right) L - bd\left(2b^2 - d^2\right)\right)
\end{aligned}$$

*Then,*

$$D_B^{TPA,H} > 0 \;\; \textit{if} \; \begin{cases} Z < 0 & \textit{or} \\ Z > 0 & \textit{and} \quad X < \frac{2b^2(2b+d)(a-(b-d)c)}{Z} \end{cases}$$

### B.2.2 Demand from type $L$ at firm $A$

As before, the highest difference in prices is when firm A copays, as this raises $p_A$ without raising $p_B$. So the relevant prices are

$$
\begin{aligned}
p_A^{\sigma<1} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} - \alpha\left(2b^2-d^2\right)\tfrac{b-(2b-d)H+(b-d)L}{2b(4b^2-d^2)}X \\
p_B^{\sigma<1} &= \tfrac{a+bc-(b-d)\bar{\omega}X}{2b-d} - \alpha\tfrac{bd}{4b^2-d^2}\left(H-1\right)X
\end{aligned}
$$

resulting in a demand from type $L$ at firm $A$ of

$$
\begin{aligned}
D_A^{\sigma<1,L} &= (1-\alpha)\left(a-bp_A^{\sigma<1}+dp_B^{\sigma<1}-(b-d)\bar{\omega}X+(b-d)(\bar{\omega}-L)X\right) \\
&= (1-\alpha)b\tfrac{a-(b-d)c-(b-d)\bar{\omega}X}{2b-d} - (1-\alpha)\alpha b\left(2b^2-d^2\right)\tfrac{b-(2b-d)H+(b-d)L}{2b(4b^2-d^2)}X \\
&\quad -(1-\alpha)\alpha d\tfrac{bd}{4b^2-d^2}(H-1)X + (1-\alpha)\alpha(b-d)(H-L)X \\
&= (1-\alpha)b\tfrac{a-(b-d)c}{2b-d} \\
&\quad +(1-\alpha)\tfrac{-4Lb^3-2b^3\alpha+2Lbd^2+2Lb^2d+8Hb^3\alpha+3Hd^3\alpha-6Lb^3\alpha-3Ld^3\alpha+3bd^2\alpha-4Hbd^2\alpha-8Hb^2d\alpha+Lbd^2\alpha+8Lb^2d\alpha}{2(4b^2-d^2)}X \\
&= (1-\alpha)b\tfrac{a-(b-d)c}{2b-d} \\
&\quad +(1-\alpha)\tfrac{\alpha\left(\left(2(b-d)\left(4b^2-d^2\right)-(2b-d)d^2\right)H-(b-d)\left(6b^2-2bd-3d^2\right)L-b\left(2b^2-3d^2\right)\right)-2b(b-d)(2b+d)L}{2(4b^2-d^2)}X
\end{aligned}
$$

This demand is positive if

$$
b\tfrac{a-(b-d)c}{2b-d} > \tfrac{2b(b-d)(2b+d)L-\alpha\left(\left(2(b-d)\left(4b^2-d^2\right)-(2b-d)d^2\right)H-(b-d)\left(6b^2-2bd-3d^2\right)L-b\left(2b^2-3d^2\right)\right)}{2(4b^2-d^2)}X
$$

It the RHS is negative, this is trivially satisfied. However, note that the RHS is positive if $\alpha$ is small. Suppose $\alpha$ approaches zero, then the condition converges to

$$
(a-(b-d)c) > b(b-d)LX
$$

which is is positive for $a$ large enough as well as for $L$ small enough.

**Lemma 10** *Let*

$$
\begin{aligned}
Y &= 2b(b-d)(2b+d)L- \\
&\quad \alpha\left(\left(2(b-d)\left(4b^2-d^2\right)-(2b-d)d^2\right)H-(b-d)\left(6b^2-2bd-3d^2\right)L-b\left(2b^2-3d^2\right)\right)
\end{aligned}
$$

*Then,*

$$
D_A^{TPA,L} > 0 \text{ if } \begin{cases} Y<0 & \text{or} \\ Y>0 & \text{and} \quad X \leq \frac{2b(2b+d)(a-(b-d)c)}{Y} \end{cases}
$$