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Research Work in Progress

n. 379, June 2010

Asymmetric information and exchange of information about product differentiation

António Brandão [1 2]
Joana Pinho [1]

[1] Faculdade de Economia, Universidade do Porto
[2] CEF.UP

U.PORTO
FEP FACULDADE DE ECONOMIA UNIVERSIDADE DO PORTO

Asymmetric information and exchange of information about product differentiation[1]

António Brandão

CEF.UP and Faculty of Economics of University of Porto.

Joana Pinho[2]

Faculty of Economics of University of Porto.

June 11th, 2010.

Abstract. We introduce asymmetric information about consumers' transportation costs (i.e., the degree of product differentiation) in the model of Hotelling (1929). When the transportation costs are high, both firms have lower profits than in the case of perfect information. Contrarily, both firms may prefer the asymmetric information case if the transportation costs are low (the informed firm always prefers the informational advantage, while the uninformed firm may or may not prefer to remain uninformed). Information sharing is ex-ante advantageous for the firms, but ex-post damaging in the case of low transportation costs. If the information is not verifiable, the informed firm always tends to announce that the transportation cost is high. To induce truthful revelation: (i) the uninformed firm must pay for the informed firm to confess that the transportation costs are low; and (ii) the informed firm must make a payment (to the uninformed firm or to a third party) for the uninformed firm to believe that the transportation costs are high.

Keywords: Hotelling model; Horizontal differentiation; Asymmetric information; Transportation costs; Information sharing.

JEL Classification Numbers: D43, D82, L13.

[1]We are grateful to João Correia da Silva, Joana Resende and Inés Macho Stadler for their useful comments.

[2]Corresponding author. Joana Pinho (080421010@fep.up.pt) acknowledges financial support from Fundação para a Ciência e Tecnologia (Ph.D. scholarship).

1 Introduction

When investing in a foreign market, firms usually have less information than the competitors operating in their home market. Jiang and Yoneyama (2008) present China as a country where this phenomenon is very common. To be competitive in the market, the foreign firms and the Chinese firms must gather information about demand. The authors argue, however, that the local firms acquire the information at a lower cost than their foreign counterparts.

Based on the work of Hotelling (1929), we model a duopoly in which firms sell horizontally differentiated products. One firm sells the product in her home market while the other is foreign. Thus, it is reasonable to consider that the information available to each firm is not the same. More precisely, we assume that only the domestic firm completely knows the consumers' transportation costs. The firm operating abroad is uncertain about the magnitude of the transportation costs.

From a geographical viewpoint, the transportation costs result from costly travels: the farther is a store from the consumer, the more costly is the product for him. Consumers can support high (physical) transportation costs due to many reasons, namely bad conditions in roadways, expensive fuel or lack of public transports.[3] In a preference-based interpretation of the model, the magnitude of the transportation costs is closely related to the degree of product differentiation. The transportation cost is the disutility that results from the purchase of a variety that is different from the consumer's favorite.

We assume exogenous locations of firms and put the emphasis of the analysis on price setting. This assumption is reasonable, for example, when a firm signs a contract with the customers, committing herself to maintain the price for a considerable period of time. In this case, a mistake in the price setting can imply serious losses for the firm. In the literature, however, the uncertainty about demand is usually assumed to affect only the firms' locations. The main arguments sustaining such assumption are the high reallocation costs and the flexibility of prices. Even if a firm sets a non optimal price, she is considered

[3]Lal and Matutes (1989) provide an additional justification for differences in transportation costs. They consider that some of the consumers are rich while the remainder are poor. The poor do not support an "opportunity cost for a shopping trip". On the contrary, the rich customers support a positive "cost of time". Following this interpretation, differences in transportation costs can also be thought as resulting from differences in consumers' wealth.

to be able to correct it in the following period. Casado-Izaga (2000), for example, assumes that firms learn about consumers' real tastes before setting prices.

When the transportation costs are high (low), the domestic firm is aware that charging a higher price has a low (high) effect on her demand. As a result, the domestic firm will set a high (low) price. The foreign firm, being uncertain about the transportation costs, sets an average price. If the transportation costs turn out to be high (low), the foreign firm captures more (less) than half of the market. We find that to be more informed about the market's characteristics is not always synonym of obtaining a higher profit. When consumers incur in high transportation costs, the foreign firm can actually obtain higher profits than the rival. In this case, to charge a lower price is compensated by a higher demand.

We compare the situation of asymmetric information to the case in which both firms have full information. When the transportation costs are high, each firm obtains more profits in the scenario of symmetric information. When these costs are low, both firms charge a higher price in the presence of asymmetric information than they would in the case of common knowledge. In this case, asymmetric information enables the domestic firm to profit more. When the transportation costs are low, the foreign firm typically benefits from being uninformed.

The foreign firm is interested in acquiring information about the transportation costs, because this increases her expected profit. This information could be obtained through a market research or from an agency responsible for attracting foreign investments. But sometimes market researches are so expensive that discourage firms to carry them on. And the data possessed by the foreign investment agency may not be sufficiently accurate (since these agencies usually gather information from several sectors of the economy). Some aspects, like consumers' preferences, are only learned by experimenting the market. Therefore, the domestic firm can be a good source of such kind of information. Liu and Serfes (2006) present the "databases with detailed records of consumers' preferences" as a typical example of information that a firm sells to another.[4] Unless issues related to the protection of consumers' privacy, this exchange of information is not generally considered

[4]In the model of Liu and Serfes (2006), the two firms sell horizontally and vertically differentiated products. Each firm is assumed to have a database with information on consumers who have purchased her product in the past. The authors analyze the incentives of a firm to directly sell her database to the competitor.

to be illegal.

Information sharing between firms may be looked in a suspicious way by antitrust authorities when it somehow leads to coordination between firms. Direct exchanges of information about prices, quantities or market shares are commonly forbidden since they are understood as attempts to facilitate collusion. We study the welfare effects of information sharing to anticipate whether communication should be allowed by an antitrust authority.

Since demand is assumed to be perfectly inelastic, a change in prices only corresponds to a transfer of surplus between consumers and firms. As a result, minimizing the consumers' transportation costs is equivalent to maximizing total surplus. In the presence of asymmetric information, transportation costs are higher (because the indifferent consumer is not in the middle of the city). Therefore, total surplus is smaller. In this sense, it is suboptimal to have one firm less informed than the other.

With communication, the firms' joint profits increase. Moreover, consumers support lower transportation costs. This could give the impression that communication is beneficial both for firms and for consumers. However, we show that the expected value of consumers' surplus decreases with information exchange. Thus, unless the antitrust authority cares about consumers and producers almost in the same way, she should not allow for communication between the firms.[5]

The expected profits of both firms are higher in the case of full information. Therefore, in the ex-ante stage, both firms are interested in commiting to communicate. However, if the information is not verifiable, the domestic firm will always have the incentive to say that the transportation costs are high (rendering the message uninformative). The message may be given credibility if there exists a third party that is able to punish the domestic firm for giving false information. Alternatively, the contract should provide incentives for the domestic firm to announce that the transportation costs are low when this is the case. We determine, in this context, the optimal incentive compatible contract to be offered by the foreign firm. According to this contract, the foreign firm pays for the information if the domestic firm reveals that consumers support low costs. However, when the transportation costs are high, the domestic firm must support a cost to make her announcement credible.

[5]Assuming that the antitrust authority maximizes a weighted average of the consumers' and the producers' expected surplus, we find that communication should not be allowed if the weight of the consumers' surplus is higher than 52%.

Even supporting this cost, the domestic firm may want to disclose her private information, since she obtains higher net profits than in the case of asymmetric information. For some values of the parameters there is no incentive compatible contract that both parties are willing to make.

Our contribution is innovative in several respects. First, by introducing uncertainty about the degree of product differentiation in the model of Hotelling. Uncertainty about the demand has been considered in the huge literature that stems from the seminal contribution of Hotelling. In the works of Harter (1996) and Casado-Izaga (2000), consumers are assumed to be spread over a subset of unitary length contained in the interval $[0, 2]$, but firms are uncertain about the actual location of the "city".[6] In a more recent contribution, Meagher and Zauner (2008) extended the model of Hotelling to the case in which firms are uncertain about the consumers' spatial distribution. Coastal cities are given as an example in which firms ignore not only the mean but also the dispersion of the population. Villas-Boas and Schmidt-Mohr (1999) also incorporate uncertainty in the spatial competition model. They study competition between two banks that provide financing to a continuum of entrepreneurs. In their model, the banks ignore the actual profitability of each entrepreneur's project. Rhee et al. (1992) consider that uncertainty is about the consumers' preferences. Preferences are assumed to be heterogeneous, having a component that firms can observe and another that is unobservable. Finally, in the models of Balvers and Szerb (1996) and of Christou and Vettas (2005), firms sell products that are differentiated both horizontally and vertically, facing uncertainty about the relative quality of their products (degree of vertical differentiation).

The model we present differs from those mentioned above in the way that uncertainty is introduced. For us, firms perfectly know consumers' preferences, but one of the firms is uncertain about consumers' transportation costs (degree of horizontal differentiation). There are several extensions of Hotelling's model that incorporate asymmetric information. Private information is commonly assumed to be about the production costs (e.g. Boyer et al., 2003 and Bester, 1998). To the best of our knowledge, the model we present is pioneer in introducing asymmetric information about a demand's characteristic.

[6] In the model of Harter (1996), there are N firms that choose locations sequentially. Afterwads, the firms that are located inside the city engage in price competition. Casado-Izaga (2000) modifies this model by allowing the firms that locate outside of the city boundaries to get a positive demand.

Our work is also innovative in addressing issues related to the exchange of information in a duopoly with horizontal differentiation. Several works have already studied the consequences and the feasibility of information sharing.[7] In the models of Gal-Or (1985), Li (1985) and Kirby (1988), no information sharing is the unique equilibrium, while Vives (1990) concluded that the expected total surplus increases with information sharing if the firms compete in quantities, and thus information sharing should be expected (the opposite is true if firms compete in prices). Assuming that information is not verifiable, Ziv (1993) studied the incentives for truthful information sharing. His conclusions are similar to ours. Firms tend to send false information, and, to overcome this problem, they may exchange transfer payments (rewarding the firm for announcing a "bad" state and penalizing the firm for claiming that the state is "good").

The remainder of the paper is structured as follows. Section 2 sets up the model. Section 3 presents the equilibrium both in the case of perfect and of asymmetric information. Section 4 analyzes the welfare consequences of asymmetric information for firms and for consumers and the expected benefits of information sharing. Section 5 studies information sharing agreements, both in the case in which firms meet prior to the existence of private information and in the case in which firms meet already having asymmetric information. Section 6 concludes. The appendix contains the proofs of most propositions.

2 The model

The model we present is based on Hotelling's (1929) model of horizontal differentiation. The market is a linear city of unitary length with two firms, 1 and 2, located at the extremes ($x_1 = 0$ and $x_2 = 1$). The products sold by the firms are identical in all respects other than the location at which they are sold. Consumers are uniformly distributed on the line and incur in a transportation cost that is quadratic in distance to buy the product (d'Aspremont et al., 1979). The utility of a consumer located at $x \in [0, 1]$ that buys from firm $i \in \{1, 2\}$ is defined as the difference between the reservation price for the ideal

[7] See Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984, 1990), Fried (1984), Gal-Or (1985, 1986), Li (1985), Sakai (1985, 1986, 1989), Shapiro (1986), Kirby (1988), Sakai and Yamato (1989), Ziv (1993) and Raith (1996).

product, V, and the costs of the purchase (price plus the transportation cost):

$$U_i\left(x\right) = V - p_i - t\left(x - x_i\right)^2.$$

The reservation price is assumed to be sufficiently high for the market to be fully covered. The demand is perfectly inelastic, with each consumer purchasing exactly one unit of the good. Therefore, the consumers' decision is only from which firm to buy the product.

Suppose that firm 1 (also designated as the *domestic* firm) operates in her home market, while firm 2 is a *foreign* firm. Thus, it is reasonable to consider that the firms have asymmetric information about consumers' characteristics. More precisely, we assume that such asymmetry only affects the knowledge about consumers' transportation costs. Both firms know that these costs are quadratic in distance. However, while firm 1 is fully informed about these costs, the rival only knows the prior probability distribution of the parameter t:

$$t = \begin{cases} t_H & \text{with probability} \quad \theta \\ t_L & \text{with probability} \quad 1-\theta \end{cases}, \tag{1}$$

where $t_H > t_L > 0$ and $\theta \in \left]0,1\right[$. The extreme cases, $\theta = 0$ and $\theta = 1$, correspond to the standard model. If $t = 0$, the products sold by the firms would not be differentiated. As it is well known, in this case the firms sell their products at the marginal cost and have zero profits.

Assumption 1. *We assume that the parameters θ, t_H and t_L are such that: $\theta \leq \frac{2}{3}\frac{t_H}{t_H - t_L}$.*

The assumption above can also be written as: $\theta \leq \frac{2}{3} \ \vee \ \frac{t_H}{t_L} < \frac{3\theta}{3\theta - 2}$.

In the following section, it becomes clear why this assumption is convenient. Essentially, we impose this additional condition on the parameters to ensure that both firms have positive demand.

The timing of the game is as follows:

1st stage: Nature chooses t (t_H with probability θ and t_L with probability $1-\theta$). The domestic firm observes the result.

2nd stage: Firms simultaneously choose prices.

Without loss of generality, we assume that both firms have zero marginal costs of production.[8]

3 Equilibrium

We start by analyzing the case of perfect information. Then, we introduce asymmetric information as described above. In both cases, the main goal is to determine the prices set by each firm and the correspondent profits.

Below, $\Pi_k^{i\theta}$ denotes the profit that the firm k obtains in the case of asymmetric information, when $t = t_i$. By Π_k^{ij} we denote the profit of firm k, when $t = t_i$ and the foreign firm believes that $t = t_j$, for $k \in \{1, 2\}, i \in \{H, L\}$ and $j \in \{H, L\}$.

3.1 Perfect information equilibrium

Suppose that the two firms know that $t = t_i$. In this case, as in the standard model, both firms are fully informed about t. Therefore, each firm charges t_i for her product and the two firms have equal demand, that is, they equally share the market. Consequently, the firms obtain the same profit, given by:

$$\Pi_1^{ii} = \Pi_2^{ii} = \frac{t_i}{2} \ , \quad i \in \{H, L\} \ .$$

3.2 Asymmetric information equilibrium

Let us now consider that the firms have asymmetric information about the transportation cost parameter. Observing the result of nature's choice, t_H or t_L, the domestic firm can choose the price, p_{1H} or p_{1L}, that maximizes her profits. The foreign firm, knowing only the prior distribution of t, has to choose the price, p_2, that maximizes her *expected* profit.

The *marginal consumer* is the consumer that is indifferent between buying the product from firm 1 or firm 2. The location of such a consumer depends on prices and on t. When

[8] Otherwise, the equilibrium prices are simply the sum of the marginal costs with the obtained prices. Thus, the profits remain the same.

$t = t_H$, the marginal consumer, $\tilde{x}_H$, satisfies:

$$U_1(\tilde{x}_H) = U_2(\tilde{x}_H) \;\Leftrightarrow\; \tilde{x}_H = \frac{1}{2} + \frac{p_2 - p_{1H}}{2t_H}\ . \tag{2}$$

Analogously, we can obtain the expression for the marginal consumer when $t = t_L$:

$$\tilde{x}_L = \frac{1}{2} + \frac{p_2 - p_{1L}}{2t_L}. \tag{3}$$

If $0 \leq \tilde{x}_i \leq 1$, for $i \in \{H, L\}$, the expression for the marginal consumer coincides with the demand of the domestic firm. The demand of firm 2 is simply $1 - \tilde{x}_i$. When $\tilde{x}_i = 0$, the firm 2 is the only one selling in the market, while $\tilde{x}_i = 1$ corresponds to the case in which the firm 1 is monopolistic.

When $t = t_H$, the profits of the domestic firm are:

$$\Pi_1^{H\theta} = p_{1H}\tilde{x}_H = p_{1H}\left(\frac{1}{2} + \frac{p_2 - p_{1H}}{2t_H}\right),$$

and her best response function is:

$$p_{1H}(p_2) = \frac{p_2}{2} + \frac{t_H}{2}.$$

Analogously, when $t = t_L$, the domestic firm's best response function is:[9]

$$p_{1L}(p_2) = \frac{p_2}{2} + \frac{t_L}{2}.$$

The uncertainty about t does not allow the foreign firm to anticipate neither the rival's response function nor her own demand. Such facts make the foreign firm uncertain about her payoff function. Thus, the foreign firm's price seeks to maximize her expected profit:

$$\begin{aligned} E\Pi_{2,AI} &= \theta\Pi_2^{H\theta} + (1-\theta)\Pi_2^{L\theta} = \\ &= \frac{1}{2t_H t_L}\left(p_2 p_{1L} t_H + p_2 t_H t_L + \theta p_2 p_{1H} t_L - \theta p_2 p_{1L} t_H - p_2^2 t_H + \theta p_2^2 t_H - \theta p_2^2 t_L\right). \end{aligned}$$

[9] The second order condition is satisfied in both cases: $\frac{\partial^2 \Pi_1^{H\theta}}{\partial p_H^2} = -\frac{1}{t_H} < 0$ and $\frac{\partial^2 \Pi_1^{L\theta}}{\partial p_L^2} = -\frac{1}{t_L} < 0$.

Hence, the best response function of firm 2 is:[10]

$$p_2\left(p_{1H}, p_{1L}\right) = \frac{(1-\theta)\, p_{1L} t_H + \theta p_{1H} t_L + t_H t_L}{2\left[(1-\theta)\, t_H + \theta t_L\right]}.$$

Combining the two firms' best response functions and solving the resulting system, we obtain the equilibrium prices:

$$\begin{cases} p_{1H} = \frac{t_H}{2} \frac{(1-\theta)t_H + (1+\theta)t_L}{(1-\theta)t_H + \theta t_L} \\ p_{1L} = \frac{t_L}{2} \frac{(2-\theta)t_H + \theta t_L}{(1-\theta)t_H + \theta t_L} \\ p_2 = \frac{t_H t_L}{(1-\theta)t_H + \theta t_L} \end{cases}. \tag{4}$$

Substituting these equilibrium prices in (2) and (3), we find the expressions for the marginal consumers:

$$\tilde{x}_H = \frac{(1-\theta)t_H + (1+\theta)t_L}{4\left[(1-\theta)t_H + \theta t_L\right]} \quad \text{and} \quad \tilde{x}_L = \frac{(2-\theta)\, t_H + \theta t_L}{4\left[(1-\theta)t_H + \theta t_L\right]}.$$

It is straightforward to see that, regardless of the parameters of the model (θ, t_H, t_L), we always have $0 \leq \tilde{x}_H \leq 1$ and $\tilde{x}_L \geq 0$. However, only by imposing Assumption 1 we can ensure that $\tilde{x}_L \leq 1$.

The domestic firm's profits are:

$$\begin{cases} \Pi_1^{H\theta} = \frac{t_H}{8} \left[\frac{(1-\theta)t_H + (1+\theta)t_L}{(1-\theta)t_H + \theta t_L}\right]^2 \\ \Pi_1^{L\theta} = \frac{t_L}{8} \left[\frac{(2-\theta)t_H + \theta t_L}{(1-\theta)t_H + \theta t_L}\right]^2 \end{cases},$$

while the *expected* profit for the foreign firm is:

$$E\Pi_{2,AI} = \frac{1}{2} \frac{t_H t_L}{(1-\theta)\, t_H + \theta t_L}. \tag{5}$$

[10]As $\frac{\partial^2 E\Pi_2}{\partial^2 p_2} = -\frac{(1-\theta)t_H + \theta t_L}{t_H t_L} < 0$, the second order condition is always verified.

Obviously, the foreign firm's profits are never equal to $E\Pi_{2,AI}$, but to the *ex-post* profits:

$$\begin{cases} \Pi_2^{H\theta} = p_2(1-\tilde{x}_H) = \frac{1}{4}t_H t_L \frac{3(1-\theta)t_H+(3\theta-1)t_L}{[(1-\theta)t_H+\theta t_L]^2} \\ \Pi_2^{L\theta} = p_2(1-\tilde{x}_L) = \frac{1}{4}t_H t_L \frac{(2-3\theta)t_H+3\theta t_L}{[(1-\theta)t_H+\theta t_L]^2} \end{cases}.$$

4 Consequences of asymmetric information

Now, we intend to analyze the impacts of asymmetric information on the pricing policies, particularly by comparing the outcomes with asymmetric information to the ones with perfect information. Moreover, we determine which of these scenarios is more profitable for firms. We end the section by analyzing impacts of asymmetric information on welfare. Precisely, we determine the consequences of asymmetric information on total surplus and on consumers' surplus. Finally, we determine the expected effects on welfare of reverting to perfect information. By doing so, we try to forecast if an antitrust authority (henceforth, AA) would welcome communication between firms. That is, we attempt to determine which situation (asymmetric or perfect information) would be desired from the standpoint of an AA.

4.1 Prices, demand and profits

We start by comparing the prices charged by the firms with and without asymmetric information.

The transportation cost parameter can be interpreted as a measure of the degree of differentiation between the products sold by the two firms. In this sense, the higher the consumers' transportation cost, the more differentiated the products are. Then, a higher value for t increases the market power of firms, softening the price competition. Both firms are aware of this, of course. However, only the domestic firm observes the actual value of t, that is, the degree of differentiation between her product and the one sold by the rival. Moreover,

$$\frac{\partial \tilde{x}_i}{\partial p_{1i}} = \frac{1}{2t_i} \;\Rightarrow\; \frac{\partial \tilde{x}_H}{\partial p_{1H}} < \frac{\partial \tilde{x}_L}{\partial p_{1L}}.$$

That is, when $t = t_H$, the domestic firm can increase her price without losing so much demand. Then, the domestic firm can set a high price for her product. As the foreign firm always charges p_2, regardless of t, it seems natural to set a lower price than the domestic firm, when $t = t_H$. The converse is true when $t = t_L$, that is, when the domestic firm knows that the two products are not very differentiated.

Recalling that t_L and t_H are the perfect information prices, the comparison of prices that follows is not surprising.

Proposition 1. *The prices under asymmetric information are such that:*

$$t_L < p_{1L} < p_2 < p_{1H} < t_H.$$

Using this relation between prices, it is straightforward to see that the two firms never have equal shares of the market, as it happens in the case of full information.

Corollary 1. *When $t = t_H$, the product sold by the foreign firm is the more demanded. Otherwise, the domestic firm has more demand.*

To decide what price to charge, the foreign firm only cares about her expected profit. However, it is interesting to compare the *ex-post* profits of both firms, that is, to find out which of the firms earns more in the presence of asymmetric information.

Proposition 2. *When $t = t_L$, the domestic firm takes advantage of her private information, achieving higher profits than the foreign firm:*

$$\Pi_1^{L\theta} \geq \Pi_2^{L\theta}.$$

When $t = t_H$, this may not be the case:

$$\Pi_1^{H\theta} \geq \Pi_2^{H\theta} \quad \textit{if and only if} \quad \frac{t_H}{t_L} \geq \frac{3-\theta}{1-\theta}\ .$$

Curiously, despite being more informed, the domestic firm may not always obtain higher profits than the rival. For example, if $t = t_H$ and $t_H < 3t_L$, the foreign firm surely profits more than the domestic. One can wonder the reason why to be more informed about consumers may not always be an advantage. As we saw before, when $t = t_H$, the domestic firm charges more per unit of product. Charging less for her product, the foreign firm captures more demand. Thus, the price gain may not be enough to offset the demand loss faced by the domestic firm. We can confirm this result in Figure 1.

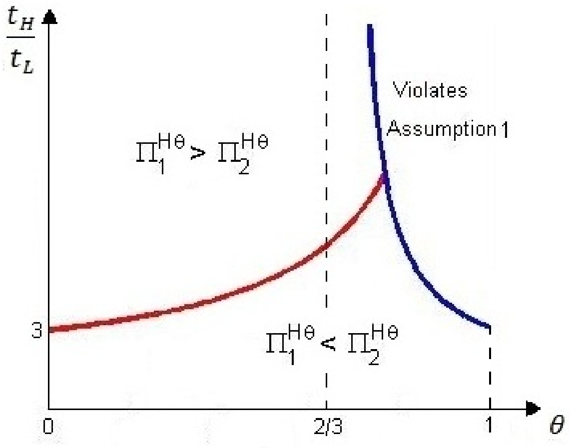

Figure 1: Comparison of the two firms' profits in the presence of asymmetric information.

It also seems interesting to determine which scenario (asymmetric or perfect information) is more profitable for the firms. Let us start by analyzing the case of the domestic firm.

Proposition 3. *When $t = t_H$, the domestic firm obtains higher profits in the case of perfect information:*

$$\Pi_1^{H\theta} \leq \Pi_1^{HH} \ .$$

However, when $t = t_L$, the domestic firm earns more in the case of asymmetric information:

$$\Pi_1^{L\theta} \geq \Pi_1^{LL} \ .$$

We can now compare the profits of the foreign firm when she ignores the actual value of t with the profits when she is perfectly informed about t.

Proposition 4. *When $t = t_H$, the foreign firm obtains higher profits in the case of perfect* *information than in the case of asymmetric information:*

$$\Pi_2^{H\theta} \leq \Pi_2^{HH} \ .$$

When $t = t_L$*, it depends on the ratio* $\frac{t_H}{t_L}$*:*

$$\begin{cases} \Pi_2^{L\theta} \geq \Pi_2^{LL} & \textit{if} \quad 1 < \frac{t_H}{t_L} \leq \frac{2\theta}{2\theta - 1} \\ \Pi_2^{L\theta} \leq \Pi_2^{LL} & \textit{if} \quad \frac{t_H}{t_L} > \frac{2\theta}{2\theta - 1} \end{cases} .$$

When the transportation costs are high, the foreign firm always obtains higher profits in the case of perfect information than in the case of asymmetric information. When $t = t_L$, there is a region of parameters $\left(\frac{t_H}{t_L} \text{ and } \theta\right)$ for which the foreign firm has higher profits in the asymmetric information scenario. This is illustrated in Figure 2.

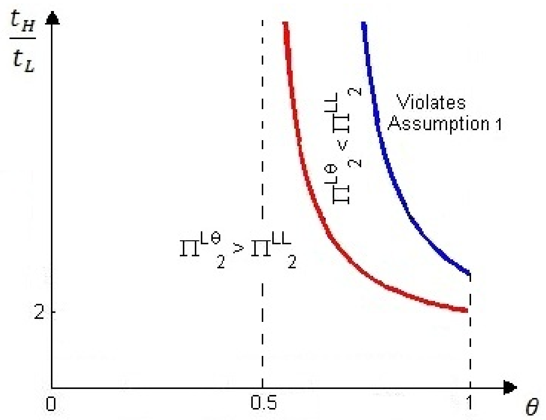

Figure 2: Comparison of the foreign firm's profits with and without asymmetric information.

We observe that, when $t = t_L$ and $\theta \leq \frac{1}{2}$, the foreign firm always profits more in the case of asymmetric information, regardless of the ratio $\frac{t_H}{t_L}$.

Combining the results in propositions 3 and 4, we conclude that, when $t = t_H$, both firms would be better off in the case of full information. On the other hand, if $t = t_L$ and $\theta \leq \frac{1}{2}$, the two firms benefit from the existence of asymmetric information.

4.2 Welfare analysis

4.2.1 Total surplus

The consumers' reservation price is assumed to be sufficiently high for the market to be fully covered. As a result, demand is perfectly inelastic: each consumer buys exactly one unit of the good. For this reason, a change in prices simply corresponds to a transfer of surplus between consumers and firms.

To study the consequences of asymmetric information on total surplus, we only need, therefore, to care about the total transportation costs, TC. Given the expression for the marginal consumer, $\tilde{x}$, we have:

$$TC\left(\tilde{x}, t\right) = \int_0^{\tilde{x}} tx^2 dx + \int_{\tilde{x}}^1 t\left(1-x\right)^2 dx = t\left(\frac{1}{3} - \tilde{x} + \tilde{x}^2\right). \tag{6}$$

To maximize the total surplus is equivalent to find the minimum of TC. It is easy to check that TC is minimized when $\tilde{x} = \frac{1}{2}$. Using the results in Corollary 1, it follows that:

Corollary 2. *If firms have asymmetric information, the total surplus is suboptimal.*

4.2.2 Consumers' surplus

Let us now analyze whether the asymmetric information between firms benefits or damages consumers.

Definition 1. *The* ***consumers' surplus*** *is defined as:*

$$CS = \tilde{x}\left(V - p_1\right) + \left(1-\tilde{x}\right)\left(V - p_2\right) - TC(\tilde{x}, t)\ , \tag{7}$$

where p_1 and p_2 are the prices charged by firm 1 and firm 2, respectively.

When $t = t_L$, symmetric information is beneficial for consumers: the transportation costs, TC, are minimal and, furthermore, the prices are lower ($t_L < p_{1L} < p_2$). When $t = t_H$, the effect of asymmetric information on consumers' surplus does not follow immediately. On the one hand, perfect information leads to the lowest value of TC, which is favorable to consumers. On the other hand, firms charge higher prices ($p_2 < p_{1H} < t_H$), which is harmful for consumers. Thus, we need to find which of these effects (price-effect or transportation cost-effect) dominates.

Let CS_{AI}^H and CS_{SI}^H be the consumers' surplus with asymmetric and with symmetric information, respectively. Using (7):

$$\begin{cases} CS_{AI}^H = V - p_2 + \tilde{x}_H\left(p_2 - p_{1H}\right) - TC(\tilde{x}_H, t_H) \\ CS_{SI}^H = V - t_H - TC\left(\frac{1}{2}, t_H\right) \end{cases}, \tag{8}$$

where:

$$TC(\tilde{x}_H, t_H) = \frac{t_H}{48\left[(1-\theta)t_H + \theta t_L\right]^2}\left[7\left(1-\theta\right)^2 t_H^2 - 2\left(7\theta^2 - 20\theta + 3\right)t_H t_L + \right. \\ \left. + \left(7\theta^2 - 6\theta + 3\right)t_L^2\right]$$

and:

$$TC\left(\frac{1}{2}, t_H\right) = \frac{t_H}{12}\ .$$

Proposition 5. *When $t = t_L$, full information is beneficial for consumers. When $t = t_H$, the converse is true: asymmetric information increases the consumers' surplus.*

Therefore, when $t = t_H$, the save in the transportation costs under full information is not enough to compensate consumers for paying higher prices. In short, the price-effect dominates, making asymmetric information between firms beneficial for consumers.

4.2.3 Expected benefits of information sharing

Now we attempt to anticipate the reaction of an antitrust authority (AA) with respect to communication between firms and the consequent reversion to the perfect information scenario. To know whether it is desirable for consumers, the AA can compare the consumers' surplus with and without asymmetric information.

In the context of our model, there is no reason for the antitrust authority to be more informed about t than the foreign firm. Otherwise, she could inform the foreign firm if this increases the consumers' welfare. For this reason, we assume that the AA only knows the prior distribution of t.

Therefore, the AA has no way to know *ex-ante* if information sharing is or not advantageous for consumers. As seen before, when $t = t_L$, full information increases the consumers' surplus. On the contrary, when $t = t_H$, consumers would be better off with asymmetric information. Due to uncertainty, the AA must base her decision on the expected welfare effect.

The expected increase of consumers' surplus that results from reverting to the full information scenario is:

$$EB_C = \theta \left[CS_{SI}^H - CS_{AI}^H \right] + (1-\theta) \left[CS_{SI}^L - CS_{AI}^L \right], \tag{9}$$

where CS_{SI}^i and CS_{AI}^i are, respectively, the consumers' surplus in the symmetric and asymmetric information scenarios, when $t = t_i$ $(i \in \{H, L\})$.

We have already determined the expressions for CS_{SI}^H and CS_{AI}^H. Analogously, when $t = t_L$, the consumers' surplus with and without asymmetric information is given by:

$$\begin{cases} CS_{AI}^L = V - p_2 + \tilde{x}_L (p_2 - p_{1L}) - TC(\tilde{x}_L, t_L) \\ CS_{SI}^L = V - t_L - TC\left(\frac{1}{2}, t_L\right) \end{cases},$$

where:

$$TC(\tilde{x}_L, t_L) = \frac{t_L}{48\left[(1-\theta)t_H + \theta t_L\right]^2} \left[\left(7\theta^2 - 8\theta + 4\right) t_H^2 + 2\theta\left(4 - 7\theta^2\right) t_H t_L + 7\theta^2 t_L^2 \right]$$

and:

$$TC\left(\frac{1}{2}, t_L\right) = \frac{t_L}{12}.$$

Substituting in (9), we obtain an explicit expression for EB_C :

$$EB_C = -\frac{13}{16} (t_H - t_L)^2 \frac{\theta(1-\theta)}{(1-\theta)t_H + \theta t_L}.$$

As EB_C is negative, the expected consumers' surplus is damaged by symmetric information. This can make the AA reluctant to allow for information sharing between firms. However, we must have in mind that frequently the main objective of AAs is to maximize a weighted sum of consumers' surplus and firms' profits.

The expected benefits of information sharing for the firms are:

$$EB_F = \theta \left[\left(\Pi_1^{HH} + \Pi_2^{HH} \right) - \left(\Pi_1^{H\theta} + \Pi_2^{H\theta} \right) \right] + (1-\theta) \left[\left(\Pi_1^{LL} + \Pi_2^{LL} \right) - \left(\Pi_1^{L\theta} + \Pi_2^{L\theta} \right) \right]. \quad (10)$$

Substituting the expressions for profits, we can simply write:

$$EB_F = \frac{7}{8}\theta \left(t_H - t_L \right)^2 \frac{1-\theta}{(1-\theta)\, t_H + \theta t_L}. \quad (11)$$

Note that EB_F is always a positive quantity, meaning that the (expected) joint profits increase with full information.

Let α and $1-\alpha$ be the weights that the antitrust authority gives to EB_C and to EB_F, respectively. The AA should allow for homogenization of information, if $\alpha EB_C + (1-\alpha)\, EB_F$ is positive. Substituting (9) and (11) on this weighted sum:

$$\alpha EB_C + (1-\alpha)\, EB_F = \frac{1}{16} \left(t_H - t_L \right)^2 \frac{\theta (1-\theta)}{(1-\theta)\, t_H + \theta t_L} (14 - 27\alpha),$$

which is greater than zero if:

$$\alpha \leq \frac{14}{27} \simeq 0.52.$$

As a result, the decision of an antitrust authority that cares about consumers and firms depends on the weight she gives to each component.

5 Exchange of information

Foreign firms commonly obtain information through agencies or through market researches. Here, we consider the domestic firm as a possible source of information: the foreign firm directly asks her competitor for information about t.

According to Vives (2006), "*in general, antitrust authorities, including the European Commission, look with suspicion at information exchanges of individual firms' data, prices and quantities in particular, because they may help monitoring deviations from collusive agreements*". However, the information exchange between firms is not always considered to be illegal. Moreover, it is not always clear for the AAs whether they should or not forbid information sharing.

In this section, we obtain the value of the information about t for the foreign firm. We show that if she offers this (fixed) amount in exchange for the information, the domestic firm always has incentives to announce that $t = t_H$.

Finally, we determine the contract that the foreign firm should propose for the rival to truthfully disclose her information.

5.1 Verifiable information

Consider the case in which the two firms have the possibility of communicating at the beginning of the game, that is, even before the domestic firm observes the value of t. We are interested in knowing if: (i) the domestic firm *ex-ante* is willing to commit herself to disclose her future information; (ii) the foreign firm is interested in such commitment.

We define the value of the information about t for the foreign firm, Ω_2, as the difference between her expected profits with information and without it. In the case of perfect information, the expected profit of the foreign firm is:

$$E\Pi_{2,SI} = \theta \Pi_2^{HH} + (1-\theta)\,\Pi_2^{LL} = \theta \frac{t_H}{2} + (1-\theta)\,\frac{t_L}{2}.$$

We have already determined, in (5), the expected profits of the foreign firm in the case of asymmetric information, $E\Pi_{2,AI}$. Hence, the value of information for the foreign firm is:

$$\begin{aligned}\Omega_2 = E\Pi_{2,SI} - E\Pi_{2,AI} &= \theta \frac{t_H}{2} + (1-\theta)\,\frac{t_L}{2} - \frac{1}{2}\frac{t_H t_L}{(1-\theta)\,t_H + \theta t_L} \\ &= \frac{1}{2}\theta\,(t_H - t_L)^2\,\frac{1-\theta}{(1-\theta)\,t_H + \theta t_L}\ . \end{aligned} \tag{12}$$

The *ex-ante* gain (or loss) for the domestic firm that results from information sharing, Ω_1, can be calculated (similarly) as the expected increase in profits:

$$\begin{aligned}\Omega_1 &= E\Pi_{1,SI} - E\Pi_{1,AI} \\ &= \theta \frac{t_H}{2} + (1-\theta)\,\frac{t_L}{2} - \\ &\quad -\theta \frac{t_H}{8}\left[\frac{(1-\theta)\,t_H + (1+\theta)\,t_L}{(1-\theta)\,t_H + \theta t_L}\right]^2 - (1-\theta)\,\frac{t_L}{8}\left[\frac{(2-\theta)\,t_H + \theta t_L}{(1-\theta)\,t_H + \theta t_L}\right]^2 \\ &= \frac{3}{8}\theta\,(t_H - t_L)^2\,\frac{1-\theta}{(1-\theta)\,t_H + \theta t_L}.\end{aligned}$$

The domestic firm also gains, *ex-ante*, with information sharing. Therefore, there will be information sharing. Recall that: if $t = t_L$, the domestic firm prefers not to share her information; while if $t = t_H$, the domestic firm profits more in the case of perfect information and, therefore, is willing to share her information. A difficulty is that these two choices are incompatible. If communication is possible, absence of communication is interpreted by the foreign firm as a signal that $t = t_L$. The domestic firm is not able to avoid revealing the true value of t.

So far, the possibility of a false information disclosure was ignored. That is, we assumed that the information is verifiable. The domestic firm was not able to lie about the magnitude of the transportation costs. This is a common assumption in the literature (Okuno-Fujiwara et al. (1990) and Gal-Or (1985)). In this case, facing a false disclosure, the foreign firm can complain in a court of law to punish the rival.

Another possibility is to assume the existence of a trade association that implements truthful communication. Both firms have to decide whether or not to join such institution before the domestic firm observes the value of t. The firms must fund this institution by paying a fee. In this case, Ω_1 and Ω_2 could be the fees paid by the domestic firm and the foreign firm, respectively. This institution could operate like this: (i) each firm pays her fee; (ii) after observing the value of t, the domestic firm reveals it to the institution, which, in turn, makes it available to the foreign firm; (iii) firms choose prices. After realizing her demand, the foreign firm detects if the message she received was true or false. To enforce truth-telling, we can consider that, in the case of a false report, the foreign firm can complain to the institution. In this case, the institution carries a market research to find out if the accusation is or not fair. If the domestic firm had, in fact, lied about t, the institution compensates the foreign firm by giving her fee back.

5.2 Unverifiable information

Now suppose that the information is not verifiable and that the domestic firm is not penalized *ex-post* if she lies about the value of t.

Proposition 6. *If the foreign firm believes in the message she receives, the domestic firm will always have the incentive to tell that* $t = t_H$*, regardless of its true value.*

Thus, if the domestic firm can send the message she prefers without a punishment, she does not represent a reliable source of information. The firm has the incentive to lie when $t = t_L$, to induce the foreign firm to charge a higher price (believing in the message, the foreign firm charges t_H instead of t_L). As a result, the domestic firm can herself set a higher price, $p_{1L}(t_H) > t_L$, achieving higher profits than if she had told the truth.

To induce truthful communication in the case of unverifiable information, the foreign firm must offer an incentive compatible contract to her rival.

When the foreign firm proposes a contract to the domestic firm, she can receive one of the following messages:

- $m = m_0$ - the contract is rejected;
- $m = m_H$ - the contract is accepted and the message is $t = t_H$;
- $m = m_L$ - the contract is accepted and the message is $t = t_L$.

If the domestic firm rejects the contract (i.e. sends the message $m = m_0$), there is no monetary transfer. Thus, to define the contract, we only need to determine the pair of transfers, (Ω_H, Ω_L), from the foreign firm to the domestic firm when $m = m_H$ and $m = m_L$, respectively.

By observing the domestic firm's response, the foreign firm can update her beliefs about $t = t_H$. We denote these posterior beliefs as $\mu(m_i)$, $i \in \{0, H, L\}$, where m_i is the message sent by the domestic firm. After receiving m_i, the foreign firm considers that t follows the distribution:

$$t = \begin{cases} t_H & \textit{with probability} \quad \mu(m_i) \\ t_L & \textit{with probability} \quad 1 - \mu(m_i) \end{cases}.$$

The revelation principle (Myerson, 1979) allows us to restrict the attention to direct mechanisms involving truthful revelation.

Definition 2. *A pair* (Ω_H, Ω_L) *is an* ***optimal contract*** *if it solves:*

$$\max_{(\Omega_H, \Omega_L)} \quad \theta\left(\Pi_2^{HH} - \Omega_H\right) + (1-\theta)\left(\Pi_2^{LL} - \Omega_L\right) \tag{13}$$

subject to the constraints:

$$\begin{cases} \Omega_L + \Pi_1^L\left[\mu\left(m_L\right)\right] \geq \Omega_H + \Pi_1^L\left[\mu\left(m_H\right)\right] & (ICC_L) \\ \Omega_L + \Pi_1^L\left[\mu\left(m_L\right)\right] \geq \Pi_1^L\left[\mu\left(m_0\right)\right] & (PC_L) \\ \Omega_H + \Pi_1^H\left[\mu\left(m_H\right)\right] \geq \Omega_L + \Pi_1^H\left[\mu\left(m_L\right)\right] & (ICC_H) \\ \Omega_H + \Pi_1^H\left[\mu\left(m_H\right)\right] \geq \Pi_1^H\left[\mu\left(m_0\right)\right] & (PC_H) \end{cases}. \tag{14}$$

The participation constraints, (PC_H) and (PC_L), imply that the domestic firm accepts the contract. The incentive compatible constraints, (ICC_H) and (ICC_L), ensure that, once the contract is accepted, the information revealed is true. Hence, the foreign firm updates her prior beliefs so that: $\mu\left(m_L\right) = 0$ and $\mu\left(m_H\right) = 1$. Determining the optimal contract also requires an assumption on how the foreign firm revises her beliefs about $t = t_H$, when receiving the message $m = m_0$. In this case, we will suppose that the firm does not revise her beliefs: that is, she keeps assuming that t follows the prior distribution, given in (1). This conjecture, so-called "*passive beliefs*", simplifies the analysis and it is widely used in the literature (Rey and Vergé, 2004; Hart and Tirole, 1990; McAfee and Schwartz, 1994). In short, after observing the message of the rival, the foreign firm considers:

$$\begin{cases} \mu\left(m_L\right) = 0 \\ \mu\left(m_H\right) = 1 \\ \mu\left(m_0\right) = \theta \end{cases}. \tag{15}$$

With this assumption, we can rewrite (14) as:

$$\begin{cases} \Omega_L + \Pi_1^{LL} \geq \Omega_H + \Pi_1^{LH} \\ \Omega_L + \Pi_1^{LL} \geq \Pi_1^{L\theta} \\ \Omega_H + \Pi_1^{HH} \geq \Omega_L + \Pi_1^{HL} \\ \Omega_H + \Pi_1^{HH} \geq \Pi_1^{H\theta} \end{cases} \Leftrightarrow \begin{cases} \Omega_L \geq \Omega_H + \Pi_1^{LH} - \Pi_1^{LL} & (ICC_L) \\ \Omega_L \geq \Pi_1^{L\theta} - \Pi_1^{LL} & (PC_L) \\ \Omega_L \leq \Omega_H + \Pi_1^{HH} - \Pi_1^{HL} & (ICC_H) \\ \Omega_H \geq \Pi_1^{H\theta} - \Pi_1^{HH} & (PC_H) \end{cases}. \tag{16}$$

It can be shown that the binding constraints are (ICC_L) and (PC_H).

Proposition 7. *Under the hypothesis of passive beliefs, the optimal contract* (y_H^*, y_L^*) *is* *such that:*

$$\begin{cases} \Omega_L^* = \Pi_1^{H\theta} - \Pi_1^{HH} + \Pi_1^{LH} - \Pi_1^{LL} \\ \Omega_H^* = \Pi_1^{H\theta} - \Pi_1^{HH} \end{cases}. \tag{17}$$

Substituting the expressions for the profits, we obtain:

$$\Omega_L^* = \frac{\Theta}{8t_L}\left\{(1-\theta)^2 t_H^3 + 2\theta(1-\theta)t_H^2 t_L + \left[1-2(1-\theta)^2\right]t_H t_L^2 + 3\theta^2 t_L^3\right\} > 0$$

and

$$\Omega_H^* = -\frac{\Theta}{8}t_H(1-\theta)\left[3(1-\theta)t_H + (1+3\theta)t_L\right] < 0,$$

where:

$$\Theta = \frac{t_H - t_L}{\left[(1-\theta)t_H + \theta t_L\right]^2}.$$

The optimal contract demands the domestic firm to share part of her profits with the competitor, when $t = t_H$.[11] This is the only way domestic firm has to make the announcement $t = t_H$ credible. As proved in Proposition 6, the she has incentives to convince her competitor that $t = t_H$. Thus, to be a reliable source of information, the domestic firm has to support a cost, when revealing that $t = t_H$. The same occurs in the model of Ziv (1993), who also allows a firm to make a "*direct payment [...] to its competitor when it sends a message*". Concerning the realism of such mechanisms, the author argues that: "*it is not unusual to see very complicated transactions that may occur in order to hide an illegal transaction between two firms. Simplifying these transactions may show that the firms are just transferring information through such payments.*"

Recall that $p_2 < t_H$, that is, when the transportation costs are high, the foreign firm charges more for her product if she is informed about t. In this case, the domestic firm gains by disclosing her private information, since the rival sets a higher price (allowing herself to practice a higher price too, as $p_{1H} < t_H$). This contract ensures that the "signaling cost" of announcing that $t = t_H$ does not exceed the benefits of perfect information.

With this optimal contract, (Ω_H^*, Ω_L^*), we can fear a false report when $t = t_H$. The domestic firm could have the temptation to lie, in order to receive the net payment Ω_L^* instead of Ω_H^*. However, the constraint (ICC_L) guarantees that this does not happen.

[11] With slight modifications, Ω_H^* could also be interpreted as advertisement spendings or charity expenses to convince the foreign firm that $t = t_H$.

The contract (Ω_H^*, Ω_L^*) ensures the foreign firm that the domestic firm will always tell the truth. However, when $t = t_L$, the contract can be so costly for the foreign firm that she prefers not to propose it. If the firm proposes (Ω_H^*, Ω_L^*) to the domestic firm, she expects to earn:

$$E\Pi_{2,C} = \theta\left(\Pi_2^{HH} - \Omega_H^*\right) + (1-\theta)\left(\Pi_2^{LL} - \Omega_L^*\right) = \theta\left(\frac{t_H}{2} - \Omega_H^*\right) + (1-\theta)\left(\frac{t_L}{2} - \Omega_L^*\right).$$

Hence, the contract (17) is proposed if and only if the resulting expected profit, $E\Pi_{2,C}$, is higher than the expected profit of the foreign firm if she is uncertain about t, $E\Pi_{2,AI}$.

Proposition 8. *The foreign firm is willing to propose the contract (17) to the domestic firm if:*

$$1 < \frac{t_H}{t_L} \leq \frac{1}{2(1-\theta)}\left(6\theta - 1 + \sqrt{1 - 12\theta + 64\theta^2}\right) .$$

The region of parameters $\left(\frac{t_H}{t_L} \text{ and } \theta\right)$ for which it is profitable (at least in expected values) for the foreign firm to propose the optimal contract are plotted in Figure 3.

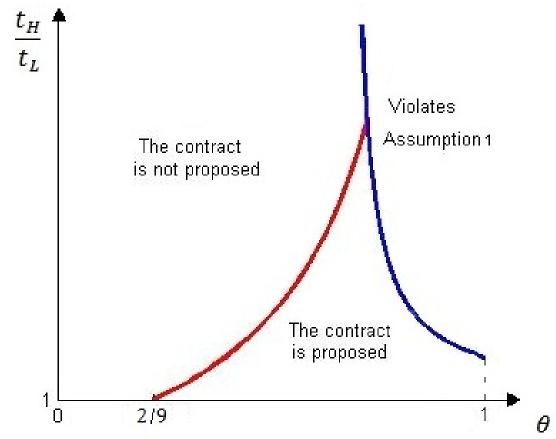

Figure 3: Willingness of the foreign firm in proposing the contract (17) to the rival.

In particular, we concluded that the foreign firm does not propose the contract (17) if the probability of high consumers' transportation costs, θ, is smaller than $\frac{2}{9}$. Moreover, a higher value for θ makes the foreign firm more willing to propose the contract. This conclusion is not surprising, since the higher is θ, the higher is the probability of receiving Ω_H^* instead of paying Ω_L^*.

6 Conclusions

There are several markets in which domestic firms have an informational advantage when competing with foreign firms. Motivated by this, we analyzed the impacts of asymmetric information about consumers' transportation costs in Hotelling's model. More precisely, we studied the effects on prices, profits and consumers' welfare. We also suggested that a foreign firm could acquire information from a domestic rival. Finally, we anticipated the probable decision of an antitrust authority on allowing or not this type of communication between the firms.

We found that the prices under asymmetric information never coincide with the prices charged when both firms have full information. More precisely, when the transportation costs are low (high), the foreign firm sets a higher (lower) price than the rival. As result, when the transportation costs are low (high), the domestic firm sells more (less).

In order to evaluate the impacts of asymmetric information on profits, we compared the earnings of the domestic firm with those of her rival. When the transportation costs are low, the domestic firm takes advantage of her private information, achieving higher profits than the rival. However, the domestic firm does not always earn more than the foreign firm. For instance, if consumers support high transportation costs and the ratio between high and low transportation costs is smaller than three, the foreign firm obtains higher profits.

We also compared the firms' profits under asymmetric information with those with full information. We noticed that, if the transportation costs are low, the existence of uncertainty can allow the firms to obtain higher profits than in the case of full information. However, when transportation costs are high, asymmetric information hurts the profits of both firms.

To appraise the willingness of the foreign firm in acquiring the information, we determined the value of this information for her. We remarked that if the foreign firm offered this amount to the rival in exchange for her information, the domestic firm will always wish to tell that consumers support high transportation costs. Unless there is an external agency involved or the data is verifiable, the domestic firm does not represent a credible source of information. Motivated by this, we designed an incentive compatible contract to be proposed by the foreign firm, in which the information is always truthfully disclosed. In such a contract, the foreign firm pays for the information when the domestic firm reveals that the transportation costs are low. If the domestic firm announces that the transportation costs are high, she has to incur in costs to make the message credible.

In addition, we analyzed the welfare consequences of communication between firms. Full information yields a Pareto-optimal outcome, with each firm capturing half of the market. Thus, from the social viewpoint, the communication between firms provides an improvement in welfare. In order to isolate the welfare effects of the information sharing on each side of the market, we studied its impacts on the expected consumers' surplus and on expected firms' profits. When consumers pay low transportation costs, the information sharing is beneficial for them, since they pay less for the product. On the contrary, when the transportation costs are high, their surplus is damaged by communication between firms. Although increasing the expected total surplus, communication between the firms decreases the expected consumers' surplus. That is, firms capture all the increase in social surplus that results from the exchange of information and still extract part of the consumers' surplus. Thus, the communication between the firms can severely damage the consumers. Consequently, an antitrust authority must weight these pros (increase in profits and total surplus) and cons (decrease in consumers' surplus) of allowing information sharing between rival firms.

7 Appendix

Proof of Proposition 1

Using the expressions for prices with asymmetric information already determined in (4):

$$p_{1H} < t_H \Leftrightarrow \frac{t_H}{2} \frac{(1-\theta)\, t_H + (1+\theta) t_L}{(1-\theta) t_H + \theta t_L} < t_H \Leftrightarrow t_H > t_L$$

and

$$p_{1L} > t_L \Leftrightarrow \frac{t_L}{2} \frac{(2-\theta)\, t_H + \theta t_L}{(1-\theta) t_H + \theta t_L} > t_L \Leftrightarrow t_H > t_L.$$

Moreover,

$$
\begin{aligned}
p_{1H} > p_{1L} \quad &\Leftrightarrow \quad \frac{t_H}{2}\frac{(1-\theta)\,t_H + (1+\theta)t_L}{(1-\theta)t_H + \theta t_L} > \frac{t_L}{2}\frac{(2-\theta)\,t_H + \theta t_L}{(1-\theta)t_H + \theta t_L} \\
&\Leftrightarrow \quad (t_H - t_L)\,[(1-\theta)\,t_H + \theta t_L] > 0.
\end{aligned}
$$

Comparing the prices charged by each firm when $t = t_H$, we obtain:

$$
p_{1H} > p_2 \Leftrightarrow \frac{t_H}{2}\frac{(1-\theta)\,t_H + (1+\theta)t_L}{(1-\theta)t_H + \theta t_L} > \frac{t_H t_L}{(1-\theta)t_H + \theta t_L} \Leftrightarrow t_H > t_L.
$$

When $t = t_L$, the condition

$$
p_2 > p_{1L} \Leftrightarrow \frac{t_H t_L}{t_H(1-\theta) + \theta t_L} > \frac{t_L}{2}\frac{(2-\theta)\,t_H + \theta t_L}{(1-\theta)t_H + \theta t_L} \Leftrightarrow t_H > t_L
$$

is always verified. □

Proof of Corollary 1

When $t = t_H$, the marginal consumer is closer to the domestic firm since:

$$
\tilde{x}_H < \frac{1}{2} \Leftrightarrow \frac{(1-\theta)t_H + (1+\theta)t_L}{4\,[(1-\theta)t_H + \theta t_L]} < \frac{1}{2} \Leftrightarrow (t_H - t_L)\,(\theta - 1) < 0\ .
$$

If $t = t_L$, the opposite is true, since $\tilde{x}_L > \frac{1}{2}$ is equivalent to the universal condition:

$$
\frac{(2-\theta)\,t_H + \theta t_L}{4\,[(1-\theta)t_H + \theta t_L]} > \frac{1}{2} \Leftrightarrow \theta\,(t_H - t_L) > 0\ . \quad \square
$$

Proof of Proposition 2

When $t = t_L$, the domestic firm obtains higher profits than the rival, since:

$$
\begin{aligned}
\Pi_1^{L\theta} \geq \Pi_2^{L\theta} \quad &\Leftrightarrow \quad \frac{t_L}{8}\left(\frac{(2-\theta)\,t_H + \theta t_L}{(1-\theta)\,t_H + \theta t_L}\right)^2 \geq \frac{1}{4} t_H t_L \frac{(2-3\theta)\,t_H + 3\theta t_L}{[(1-\theta)\,t_H + \theta t_L]^2} \\
&\Leftrightarrow \quad [(2-\theta)\,t_H + \theta t_L]^2 - 2t_H\,[(2-3\theta)\,t_H + 3\theta t_L] \geq 0 \\
&\Leftrightarrow \quad \theta\,(t_H - t_L)\,[2t_H + \theta\,(t_H - t_L)] \geq 0\ .
\end{aligned}
$$

When $t = t_H$, we have that $\Pi_1^{H\theta} \geq \Pi_2^{H\theta}$ if:

$$\begin{aligned}
& \frac{t_H}{8}\left[\frac{(1-\theta)\,t_H + (1+\theta)\,t_L}{(1-\theta)\,t_H + \theta t_L}\right]^2 \geq \frac{t_H}{4} t_L \frac{3\,(1-\theta)\,t_H + (3\theta-1)\,t_L}{[(1-\theta)\,t_H + \theta t_L]^2} \\
\Leftrightarrow\ & [(1-\theta)\,t_H + (1+\theta)\,t_L]^2 - 2t_L\,[3\,(1-\theta)\,t_H + (3\theta-1)\,t_L] \geq 0 \\
\Leftrightarrow\ & (t_H - t_L)\,(1-\theta)\,(t_H - 3t_L - \theta t_H + \theta t_L) \geq 0 \\
\Leftrightarrow\ & \frac{t_H}{t_L} \geq \frac{3-\theta}{1-\theta}\ . \quad \square
\end{aligned}$$

Proof of Proposition 3

When $t = t_H$, the domestic firm profits more in the case of perfect information, $\Pi_1^{H\theta} \leq \Pi_1^{HH}$, if:

$$\begin{aligned}
& \frac{t_H}{8}\left[\frac{(1-\theta)\,t_H + (1+\theta)\,t_L}{(1-\theta)\,t_H + \theta t_L}\right]^2 \leq \frac{t_H}{2} \\
\Leftrightarrow\ & \left[\frac{(1-\theta)\,t_H + (1+\theta)\,t_L}{(1-\theta)\,t_H + \theta t_L} - 2\right]\left[\frac{(1-\theta)\,t_H + (1+\theta)\,t_L}{(1-\theta)\,t_H + \theta t_L} + 2\right] \leq 0 \\
\Leftrightarrow\ & \frac{(1-\theta)\,t_H + (1+\theta)\,t_L}{(1-\theta)\,t_H + \theta t_L} - 2 \leq 0 \\
\Leftrightarrow\ & (t_H - t_L)\,(\theta - 1) \leq 0\ ,
\end{aligned}$$

which is always true. The inequality $\Pi_1^{L\theta} \geq \Pi_1^{LL}$ is equivalent to:

$$\begin{aligned}
& \frac{t_L}{8}\left[\frac{(2-\theta)\,t_H + \theta t_L}{(1-\theta)\,t_H + \theta t_L}\right]^2 \geq \frac{t_L}{2} \Leftrightarrow \left[\frac{(2-\theta)\,t_H + \theta t_L}{(1-\theta)\,t_H + \theta t_L} - 2\right]\left[\frac{(2-\theta)\,t_H + \theta t_L}{(1-\theta)\,t_H + \theta t_L} + 2\right] \geq 0 \\
\Leftrightarrow\ & (2-\theta)\,t_H + \theta t_L - 2\,[(1-\theta)\,t_H + \theta t_L] \geq 0 \Leftrightarrow \theta\,(t_H - t_L) \geq 0\ . \quad \square
\end{aligned}$$

Proof of Proposition 4

The condition $\Pi_2^{H\theta} \leq \Pi_2^{HH}$ is satisfied if:

$$\begin{aligned}
& \frac{t_H}{4} t_L \frac{3\,(1-\theta)\,t_H + (3\theta-1)\,t_L}{[(1-\theta)\,t_H + \theta t_L]^2} \leq \frac{t_H}{2} \\
\Leftrightarrow\ & t_L\,[3\,(1-\theta)\,t_H + (3\theta-1)\,t_L] \leq 2\,[(1-\theta)\,t_H + \theta t_L]^2 \\
\Leftrightarrow\ & (t_H - t_L)\,(1-\theta)\,(t_L - 2t_H + 2\theta t_H - 2\theta t_L) \leq 0\ .
\end{aligned}$$

As $t_H > t_L$ and $\theta \in (0,1)$, the inequality above is equivalent to:

$$(1-2\theta)\, t_L - 2\,(1-\theta)\, t_H \leq 0 \;\Leftrightarrow\; t_H \geq \frac{1-2\theta}{2\,(1-\theta)} t_L \;, \tag{18}$$

which is always true, since, $\forall \theta \in]0,1[$, $\frac{1-2\theta}{2(1-\theta)} t_L < t_L$. We also have that:

$$\begin{aligned}
\Pi_2^{L\theta} \geq \Pi_2^{LL} \quad &\Leftrightarrow \quad \frac{t_L}{4} t_H \frac{(2-3\theta)\, t_H + 3\theta t_L}{\left[(1-\theta)\, t_H + \theta t_L\right]^2} \geq \frac{t_L}{2} \\
&\Leftrightarrow \quad t_H \left[(2-3\theta)\, t_H + 3\theta t_L\right] \geq 2 \left[(1-\theta)\, t_H + \theta t_L\right]^2 \\
&\Leftrightarrow \quad \theta\,(t_H - t_L)\,(t_H - 2\theta t_H + 2\theta t_L) \geq 0 \\
&\Leftrightarrow \quad (1-2\theta)\, t_H + 2\theta t_L \geq 0.
\end{aligned}$$

The inequality above is equivalent to:

$$\begin{cases}
t_H \geq -\frac{2\theta}{1-2\theta} t_L & if \quad \theta < \frac{1}{2} \\
t_L \geq 0 & if \quad \theta = \frac{1}{2} \\
t_H \leq \frac{2\theta}{2\theta-1} t_L & if \quad \theta > \frac{1}{2}
\end{cases} .$$

When $\theta \leq \frac{1}{2}$, the conditions for t_H are verified. In the case that $\theta > \frac{1}{2}$, the interval $\left]t_L, \frac{2\theta}{2\theta-1} t_L\right]$ is non empty and:[12]

$$\begin{cases}
\Pi_2^{L\theta} \geq \Pi_2^{LL} & if \quad \frac{t_H}{t_L} \in \left]1, \frac{2\theta}{2\theta-1}\right] \\
\Pi_2^{L\theta} \leq \Pi_2^{LL} & if \quad \frac{t_H}{t_L} \in \left]\frac{2\theta}{2\theta-1}, \frac{3-\theta}{1-\theta}\right[
\end{cases} . \quad \square$$

Proof of Proposition 5

When $t = t_L$, the symmetric information is beneficial for consumers since firms charge a lower price and, as $\tilde{x} = \frac{1}{2}$, the total transportation costs are lower. When $t = t_H$,

[12] Recall that the assumption (1) must also be verified.

substituting the expressions for TC in (8) we obtain:

$$\begin{aligned} CS_{SI}^{H} < CS_{AI}^{H} &\Leftrightarrow \frac{1}{16}t_H\left(t_H - t_L\right)\frac{1-\theta}{\left[(1-\theta)t_H+\theta t_L\right]^2}\left(t_L - 13t_H + 13\theta t_H - 13\theta t_L\right) < 0 \\ &\Leftrightarrow 13\left(1-\theta\right)\left(t_L - t_H\right) - 12t_L < 0 \\ &\Leftrightarrow 13\left(1-\theta\right)t_L - 12t_L < 13\left(1-\theta\right)t_H \\ &\Leftrightarrow t_H > t_L - \frac{12t_L}{13\left(1-\theta\right)} \ , \end{aligned}$$

which is always true. $\square$

Proof of Proposition 6

Suppose that $t = t_L$. If the domestic firm announces that $t = t_H$, the foreign firm sets $\hat{p}_2 = t_H$ and the domestic firm charges:

$$\hat{p}_1 = \frac{t_H + t_L}{2} < t_H = \hat{p}_2 \ .$$

Then, the expression for marginal consumer is:

$$\tilde{x}_L = \frac{1}{4t_L}\left(t_H + t_L\right)$$

and the domestic firm's profits are:

$$\Pi_1^{LH} = \frac{1}{8t_L}\left(t_H + t_L\right)^2$$

Therefore, she is interested in lying about t if:

$$\Pi_1^{LL} > \Pi_1^{LH} \Leftrightarrow \frac{t_L}{2} > \frac{1}{8t_L}\left(t_H + t_L\right)^2 \Leftrightarrow \left(t_L - t_H\right)\left(3t_L + t_H\right) > 0 \ ,$$

which is always true. When $t = t_H$ but the foreign firm takes t_L as been the true value for t, she charges $\check{p}_2 = t_L$. In this case, the domestic firm sets a price equal to:

$$\check{p}_1 = \frac{t_H + t_L}{2} > t_L = \check{p}_2$$

Given these prices, the marginal consumer is located at:

$$\tilde{x}_H = \frac{1}{4t_H}(t_H + t_L)$$

and:

$$\Pi_1^{HL} = \frac{1}{8t_H}(t_H + t_L)^2$$

Therefore, the domestic firm chooses to tell the truth since:

$$\Pi_1^{HH} > \Pi_1^{HL} \Leftrightarrow \frac{t_H}{2} > \frac{1}{8t_H}(t_H + t_L)^2 \Leftrightarrow (t_H - t_L)(3t_H + t_L) > 0. \quad \square$$

Proof of Proposition 7

Suppose that (ICC_L) and (PC_H) are both binding. Therefore:

$$\begin{cases} \Omega_L^* = \Pi_1^{H\theta} - \Pi_1^{HH} + \Pi_1^{LH} - \Pi_1^{LL} \\ \Omega_H^* = \Pi_1^{H\theta} - \Pi_1^{HH} \end{cases}.$$

We must prove that (Ω_L^*, Ω_H^*) also satisfy the remaining constraints, (PC_L) and (ICC_H). Starting with (PC_L):

$$\begin{aligned} \Omega_L^* \geq \Pi_1^{L\theta} - \Pi_1^{LL} \;&\Leftrightarrow\; \Pi_1^{H\theta} - \Pi_1^{L\theta} \geq \Pi_1^{HH} - \Pi_1^{LL} \\ &\Leftrightarrow\; \frac{1}{8}\frac{(t_H - t_L)^2}{(t_H - \theta t_H + \theta t_L)^2}\left(t_H - 2\theta t_H + \theta^2 t_H - \theta^2 t_L\right) \geq -\frac{1}{8t_L}(t_H - t_L)^2 \\ &\Leftrightarrow\; \frac{t_H}{t_L}\frac{1-\theta}{(t_H - \theta t_H + \theta t_L)^2}(t_H + t_L - \theta t_H + \theta t_L) \geq 0 \\ &\Leftrightarrow\; (1-\theta)\, t_H + (1+\theta)\, t_L \geq 0 \;, \end{aligned} \tag{19}$$

which is always true. With respect to (ICC_H), we also obtain a universal condition:

$$\begin{aligned} \Omega_L^* \;&\leq\; \Omega_H^* + \Pi_1^{HH} - \Pi_1^{HL} \Leftrightarrow \Pi_1^{LH} + \Pi_1^{HL} \leq \Pi_1^{LL} + \Pi_1^{HH} \\ &\Leftrightarrow\; \frac{1}{8t_L}(t_H + t_L)^2 + \frac{1}{8t_H}(t_H + t_L)^2 \leq \frac{t_L + t_H}{2} \Leftrightarrow \frac{1}{8} \leq \frac{1}{2}. \end{aligned}$$

Using (19):

$$\Pi_1^{H\theta} - \Pi_1^{HH} \geq \Pi_1^{L\theta} - \Pi_1^{LH} > \Pi_1^{LL} - \Pi_1^{LH} \;\Rightarrow\; \Omega_L^* > 0.$$

Finally, as $\Pi_1^{H\theta} \leq \Pi_1^{HH}$, Ω_H^* is trivially non positive. $\square$

Proof of Proposition 8

The foreign firm proposes the contract (17) to the rival if:

$$\begin{aligned} &E\Pi_{2C} \geq E\Pi_2 \Leftrightarrow \theta\left(\Pi_2^{HH} - \Omega_H^*\right) + (1-\theta)\left(\Pi_2^{LL} - \Omega_L^*\right) \geq \theta\Pi_2^{H\theta} + (1-\theta)\,\Pi_2^{L\theta} \\ \Leftrightarrow\ &\theta\left(2\Pi_2^{HH} - \Pi_1^{H\theta}\right) + (1-\theta)\left(2\Pi_2^{LL} - \Pi_1^{H\theta} + \Pi_2^{HH} - \Pi_1^{LH}\right) \geq \frac{1}{2}\frac{t_H t_L}{(1-\theta)\,t_H + \theta t_L}\ , \end{aligned}$$

which is equivalent (substituting the expressions for profits) to:

$$\begin{aligned} &-\frac{(t_H - t_L)^2 (1-\theta)}{8t_L\left[(1-\theta)\,t_H + \theta t_L\right]^2}\left(\theta^2 t_H^2 + 6\theta^2 t_H t_L - 7\theta^2 t_L^2 - 2\theta t_H^2 - 7\theta t_H t_L + t_H^2 + t_H t_L\right) \geq 0 \Leftrightarrow \\ \Leftrightarrow\ &(1-\theta)^2 t_H^2 + (1-\theta)(1-6\theta)\,t_L t_H - 7\theta^2 t_L^2 \leq 0. \end{aligned} \tag{20}$$

The roots of $(1-\theta)^2 t_H^2 + (6\theta^2 - 7\theta + 1)\,t_L t_H - 7\theta^2 t_L^2$ are:

$$\begin{cases} \underline{t}_H = \frac{t_L}{2(1-\theta)}\left(6\theta - 1 - \sqrt{1 - 12\theta + 64\theta^2}\right) \\ \bar{t}_H = \frac{t_L}{2(1-\theta)}\left(6\theta - 1 + \sqrt{1 - 12\theta + 64\theta^2}\right) \end{cases}.$$

As $1 - 12\theta + 64\theta^2$ is always positive, the inequality (20) is verified when:

$$t_H \in \left[\underline{t}_H, \bar{t}_H\right] \cap \left]t_L, +\infty\right[.$$

Moreover, as $\underline{t}_H < 0$, the set $\left[\underline{t}_H, \bar{t}_H\right] \cap \left]t_L, +\infty\right[$ is non empty if:

$$\begin{aligned} \bar{t}_H > t_L \ &\Leftrightarrow\ \frac{t_L}{2(1-\theta)}\left\{6\theta - 1 + \sqrt{1 - 12\theta + 64\theta^2}\right\} > t_L \\ &\Leftrightarrow\ \sqrt{1 - 12\theta + 64\theta^2} > 3 - 8\theta. \end{aligned}$$

If $\theta \in \left]\frac{3}{8}, 1\right[$, then $3 - 8\theta < 0$ and the inequality above is verified. If $\theta \in \left]0, \frac{3}{8}\right]$, the inequality is equivalent to:

$$1 - 12\theta + 64\theta^2 > (3-8\theta)^2 \Leftrightarrow 1 - 12\theta + 64\theta^2 - (3-8\theta)^2 > 0 \Leftrightarrow \theta > \frac{2}{9}. \quad \square$$

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