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Schultz, Christian

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Christian Schultz

Centre for Industrial Economics
Department of Economics, University of Copenhagen
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Christian Schultz[*†]

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Abstract

The paper considers tacit collusion in markets which are not fully transparent on both sides. Consumers only detect prices with some probability before deciding which firm to purchase from, and each firm only detects the other firm's price with some probability. Increasing transparency on the producer side facilitates collusion, while it increasing transparency on the consumer side makes collusion more difficult. Conditions are given under which increases in a common factor, affecting transparency positively on both sides, are pro-competitive. With two standard information technologies, this is so, when firms are easier to inform than consumers.

Keywords: Transparency, Tacit Collusion, Cartel Theory, Competition Policy, Internet. JEL: L13 ,L40

1 Introduction

The effect of market transparency on competition is much debated, see for instance OECD (2001). The EU Council finds that "The transparency of energy prices contributes to the creation and smooth operation of the internal energy market" and Council Directive 90/377/EEC specifies a procedure to improve the transparency of gas and electricity prices charged to

[*]Department of Economics, University of Copenhagen, cs@econ.ku.dk, www.econ.ku.dk/CSchultz

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industrial end-users, see Official Journal (1990). While consumers previously had to exert considerable effort to compare prices in many markets such comparisons are now often avaliable with a click on the mouse. It is often suggested that consumer or government agencies should counter weak competition by setting up price comparison sites and thus improve transparency on the consumer side of the market. For instance, the Danish National Consumer Agency (a government agency) hosts price comparison pages for banks, cellphones, natural gas, and home utilities (see http://www.forbrug.dk/test/priser/). Evidently, such facilities may also be used by firms. It is an interesting, and so far unresolved issue, whether an increase in price transparency affecting *both* sides of the market at the same time is to be considered pro-competitive. This paper seeks to make some headway on this issue.

Improved transparency on the producer side is mostly viewed as anti-competitive since it is thought to facilitate tacit collusion, see for instance, Stigler (1964), Green-Porter, (1984), Tirole (1988), Kühn and Vives (1995) and Kühn (2001). Transparency on the consumer side is thought to have opposite effects. Here the arguments usually refer to a static setting, building on results of the search literature of the 80'ies like Varian (1980), Stahl (1989), Burdett and Judd (1983) and many others. An exeption is Schultz (2005), where I show that in a differentiated Hotelling market improved transparency on the consumer side makes tacit collusion more difficult, while it has (almost) no effect if the market is almost homogeneous. The present paper investigates the effects on tacit collusion from a change of a common factor increasing transparency on both sides of the market. In the homogeneous market, the effect is anti-competitive, since only the producer side matters. In a differentiated market, however, this is not so. In general, the result depends on the relative elasticities of transparency wrt the common factor on either side. However, for two of the most widely used information technologies in the literature - a simple concave technology and the model of Butters (1977) and Grossmann-Shapiro (1984) - the result is unambigous. In a sufficently differentiated market, if firms are easier to inform than consumers, an increase in a common factor promoting transparency on both sides is pro-competitive. Although perhaps surprising at first sight, the reason is intuitive: When firms are easier to inform, they are relatively well informed. Hence, increases in price transparency affects the more poorly informed consumer side relatively more, and this is the crucial issue.

Hence, from a competition policy perspective the results of this paper points to that in *homogeneous* markets, competition authorities (and consumer agencies) should not try to further price transparency. Price transparency only affect competition through the producer side, and this effect is *anti-competitive*. In (sufficiently) *differentiated* markets, the relation is different. Here both producer and consumer side effects are relevant and they counter each other. Under standard assumptions on information proliferation, the consumer side effects dominate and measures which increase transparency on both sides are likely to be *pro-competitive*.

We assume that a consumer learns prices with a given probability less than one. Hence, only a fraction of consumers will be informed about prices as in Varian (1980). We identify transparency on the consumer side with the fraction of informed consumers. Similarly, on the producer side, firms learn each others' prices with some probability only. Since market demand is stochastic, this implies that in a collusive equilibrium, a firm only learns that another firm has deviated with some probability. We study trigger strategy equilibria where a punishment is only initiated if a firm learns that the other firm has deviated. Firms' collusive strategies thus involve price-monotoring schemes for the competitiors. These equilibria have the virtue that they are simple and they accord well with the evidence from many cartel cases. It is well known that implicit cartels may also rely punishment phases initiated when demand conditions turned out to be sufficiently bleak, i.e where firms employ sales monotoring schemes. While such startegies are intellectually appealing, it appears that the more simple strategies considered here are in fact used by many of the cartels we know of. Furthermore, diseminating information about members pricing and sales has traditionally been core business for established cartels, so that deviations from adhering to the collusion cannot go undetected. Such behavior is consistent with trigger strategies based on observed deviations from collusion.

Market transparency has been analyzed in various ways in the literature. An early contribution is Varian (1980) who studies a homogeneous market where some consumers are unaware of prices. In this setting the firms' expected prices and profits decrease in the level of market transparency. The search literature, see for instance Burdett and Judd (1993) or Stahl (1989) develops this further: When search costs are lowered, search intensifes and so does competition. A recent literature has taken op this lead, Ellisson and Wolitzky (2008) extend Stahl's work to include delibarate obfuscation by the firms, so that consumer's search costs increase. See also Wilson (2008). In this literature firms strategically make consumer search costly. The voluminous literature on advertising, see the survey in Bagwell (2007), also discusses markets where some parties are uninformed about prices, but here firms actively try to spread information on the consumer side. Anderson and Renault (1999) extend search to include product characteristics as well as prices and show that prices rise with search costs. Gabaix and Laibson (2006) and Armstrong and Chen (2008) consider "inattentive consumers", who are not aware of quality and price or quality and price of an add on. While these contributions all adress different issues of transparency, they are concerned with static outcomes, while my paper focusses on the effects on collusion from transparency. Secondly, while many of these papers seek to endogenize transparency in various ways, I focus on the case, where transparency is exogenous and potentially affected by an agent or authority outside the market such as a consumer agency.

Nilsson (1999) considers a *homogeneous* market with costly consumer search a la Burdett and Judd (1993). He shows that lower search costs facilitate collusion, since the profits in the collusive and punishment phases are affected differently by changes in search costs as consumers are induced to search more in the punishment phase, which consists of infinite repetition of a mixed strategy Nash equilibirum. In Schultz (2005) as well as in the present paper, the fraction of informed consumers does not differ in the collusive and punishment phases. Herre and Rasch (2009) show that the effect of transparency on the consumer side on tacit collusion is not unambigious if one relaxes the assumptions of the standard differentiated Hotelling model.

The organization of the paper is the following. Section 2 introduces the market. The one period equilibrium is characterized in Section 3. Section 4 introduces tacit collusion, and sections 5 and 6 treat high and low product differentiation respectively. Section 7 offers some concluding comments.

2 The market

We consider a Hotelling market with a continuum of consumers. Consumer x is located at $x \in$ [0,1]. A consumer wishes to buy zero or s units of the good where s is a stochastic variable distributed according to the cdf $\psi(s)$ with mean $\int s d\psi(s) = 1$. The variable s introduces stochastic demand in a simple way into the model. We assume that $[0, 1]$ is contained in the support of ψ, so that any decline in demand below the mean is possible. The two firms are located at 0 and 1 respectively. A consumer buying s goods at the price p from a firm she is located y away from receives utility $(u - p_0 - ty) s$. The parameter $t > 0$ is the transportation cost, reflecting the degree of product differentiation or "pickiness" of the consumers. All consumers are potential costumers at each firm: $u \geq t$. If a consumer is informed about both firms' prices she is indifferent between buying from either firm if she is located at

$$x(p_0, p_1) \equiv \frac{1}{2} + \frac{p_1 - p_0}{2t}. \tag{1}$$

A fraction ϕ of the consumers are informed about both firms' prices, while the rest are uninformed. An uninformed consumer cannot learn prices by visiting both firms, she can only visit one firm in a period. The firms' locations are known to all consumers. The variable ϕ is our measure of market transparency at the consumer side. Both information types of consumers are uniformly distributed on locations. An uninformed consumer has an *expectation* p_i^e of firm $i's$ price. If she is located y away from firm i, her *expected* utility from buying one unit from i is $u - p_i^e - ty$. She is indifferent between buying from the two firms, if she is located at $x(p_0^e, p_1^e)$.

In a period, the time line is as follows: First s realises and it is not observed by firms. Then firms set prices, which are observed by some consumers only, the rest form expectations. Consumers decide on which firm to go to - if any. If an uninformed consumer arrives at a firm and finds that the price is higher than expected, she may decline to buy. Finally, transactions take place.

We will assume that the fraction of informed consumers is sufficiently high such that

$$\frac{t}{u} < \frac{2\phi}{2 + \phi}; \tag{2}$$

this will imply that the market is covered in a pure strategy Nash equilibrium.

We will focus on symmetric equilibria where $p_0^e = p_1^e = p^e$. As will become clear, the equilibrium price will be so low (at most $u - t/2$) that all consumers buy and each firm faces $(1-\phi)/2$ uninformed consumers. The number of consumers visiting firm 0 can therefore be written without explict reference to the expected prices as

$$D(p_0, p_1, \phi) = \begin{cases} \phi + \frac{1-\phi}{2} & \text{if} \quad p_0 < p_1 - t \\ \phi\left(\frac{1}{2} + \frac{p_1 - p_0}{2t}\right) + \frac{1-\phi}{2} & \text{if} \quad p_1 - t \leq p_0 \leq p_1 + t \\ \frac{1-\phi}{2} & \text{if} \quad p_1 + t \leq p_0 \leq u - \frac{t}{2} \\ \frac{1-\phi}{2}\left(\frac{u-p_0}{t}\right) & \text{if} \quad p_1 = u - \frac{t}{2} \leq p_0 \leq u. \end{cases} \tag{3}$$

Firm $0's$ demand equals the number of visiting consumers times s, $D(p_0, p_1, \phi)s$. As the mean of s equals one, the expected demand equals $D\left(p_0, p_1, \phi\right)$. Marginal costs are constant and we normalize them to zero, so firm $0's$ profit in a period is $p_0 D(p_0, p_1 \phi)s$ and the expected profit π_0 equals $p_0 D(p_0, p_1 \phi)$.

Under (2) the monopoly price, p^m, is given as $p^m = u - t/2$.

3 One period equilibrium

The one period Nash equilibrium may be in pure or mixed strategies depending on the degree of product differentiation relative to the maximal willingness to pay, t/u, and the transparency of the market, ϕ. We first consider the case where the equilibrium is in pure strategies.

Each firm chooses the price to maximize the expected profit taking as given the other firm's price. In a symmetric equilibrium, the firms set the same price, serve both informed and uninformed consumers, and the relevant part of the demand function is given by the second line in (3). The Nash equilibrium price, p^N, and expected profit, π^N, are

$$p^N = \frac{t}{\phi},\ \pi^N = \frac{t}{2\phi}. \tag{4}$$

An increase in consumer transparency, ϕ, increases competition and lowers the Nash-equilibrium price and profit. When firms choose prices, they take into account that a price decrease is only noticed by the informed consumers. An increase in consumer transparency makes demand more elastic and competition more intense. In the one shot game the firms therefore - jointly –

have no interest in promoting consumer transparency. It is straightforward to check that the second order condition for maximum is fulfilled.[1]

When the Nash equilibrium is in pure strategies, then

$$\gamma \equiv \frac{p^m - p^N}{p^N}$$

is a measure of the relative gains to firms from monpoly pricing relative to competitive pricing. Evidently, the gain is a function of u, t and ϕ. We can rewrite condition (2) as

$$\gamma > 0. \tag{2'}$$

When goods are close substitutes, $p^N = t/\phi$ becomes very low and will not be an equilibrium price since it becomes a better option for a firm to raise its price to the monopoly price $p^m = u - t/2$ and only sell to the $(1-\phi)/2$ uninformed consumers who visit the firm[2]. This gives higher profit than p^N if the degree of product differentiation is so low that

$$\frac{t}{u} < \frac{2(1-\phi)\phi}{(1+\phi)(2-\phi)} \Leftrightarrow \gamma > \frac{\phi}{1-\phi}. \tag{5}$$

When (5) is fulfilled, product differentiation is so low that a pure strategy equilibrium does not exist. Varian (1980) shows that in a homogeneous market where a fraction ϕ of the consumers are uninformed, there are no pure strategy Nash equilibria, but a symmetric mixed strategy equilibrium exists. The same happens in the Hotelling model, when the goods become close substitutes. Schultz (2005) characterizes the symmetric mixed strategy equilibrium. The characterization does not allow closed form solutions, but it is shown (in Lemma 1) that as the transport cost t tends to zero, the limiting expected profit of each firm is[3]

$$\lim_{t \to 0} \pi^N = \frac{1-\phi}{2} u. \tag{6}$$

[1] In deriving the equilibrium we assumed that the market is covered and the second line of (3) is relevant, hence it should not be advantageous to undercut the other firm by t and gain the whole informed market. This takes that $\left(\frac{t}{\phi} - t\right)\left(\phi + \frac{1-\phi}{2}\right) < \frac{t}{2\phi}$, which is fulfilled for all positive ϕ and t. Under assumption (2) the market is covered in the Nash equilibrium.

[2] If the firm decides to sell only to a fraction of the uninformed consumers arriving, the best price solves $\max_{p_0} (1-\phi) \frac{u-p_0}{t} p_0$, if it decides to sell to all, $p_0 = u - \frac{t}{2}$. For small t, the best choice is $p_0 = u - \frac{t}{2}$

[3] Since no confusion should be possible, we abuse notation slightly by using π^N to indicate the expected profit in the pure as well as in the mixed strategy equilibrium.

The result is intuitive: It is always an option for a firm to charge the reservation price, which equals u when transportation costs vanish, and only serve the uninformed consumers arriving. In a mixed strategy equilibrium, each price in the support of the distribution must give same expected profit, and hence the expected profit is given by (6). When goods are almost homogeneous, the market works as if firms extract almost all possible rent from the uninformed consumers and none from the informed. A similar result was obtained by Varian for the homogeneous market. In Schultz (2005) it is also shown that

$$\lim_{t \to 0} \frac{\partial \pi^N}{\partial \phi} = -\frac{u}{2}. \tag{7}$$

4 Tacit Collusion

Now we consider the repeated game. There are infinitely many periods, $\tau = 0, ..., \infty$. In each period the market is as described above. The size of the market s differs over periods, we assume that s is drawn from the distribution ψ independently over the periods. Firms seek to maximize the discounted sum of expected profits and both have the discount factor δ, which fulfills $0 < \delta < 1$. We will assume that a consumer's information type (as well as her location) is the same in all periods.

So far we have concentrated on market transparency on the consumer side. Whether firms can observe each others' prices ex post is not important for the one period analysis but it is for the dynamic analysis. We will identify transparency on the producer side with the probability that a firm observes the other firm's price. Let this probability be η, where $0 < \eta \leq 1$. We will assume that if a firm observes the other firm's price, then it is common knowledge. It may, for instance, be the case that the price is put on an internet side run by an independent consumer agency known to both firms, news papers may cite the price, or they are both aware that a person has disclosed the information. It may also be the case that the firms deliberately have made an arrangement for sharing of information as many cartels have in fact done.

The fact that firms may not observe each others' price can affect the possibility of maintaining tacit collusion. If firms collude on a high price, a firm may deviate in a period to a lower price and the other firm may not see it, but its sales will be affected. However, since the market demand is stochastic this lowering in sales may also be due to slack demand. We will focus on trigger strategy equilibria where punishment phases are only initiated when firms observe a deviation. Here transparency on the producer side will have a direct effect.

As is well known, Green and Porter (1984) show that even though firms do not observe each others strategic variables, they may nevertheless collude relying on punishment phases which are initiated after periods of very slack demand. One could of course also conceive of such equilibria in our model, but we will not consider this extension here. The strategies we consider here have the virtue that they are simple: "I punish you if I catch you cheating". There are many examples of cartels, where the punishment strategies have relied on punishing deviations when the deviator is caught in the act. An European example is provided by the "Wood pulp" case, where 34 firms were fined by the European Commission for collusion. In its decision (Official Journal, 1985) the Commission describes in detail how the parties coordinated and monitored prices. The commission found evidence that the explicit threats of punishments were made. It cites a document summarizing a meeting between a number of the firms: "The Finns will respect the Spanish dominance in Spain if ENCE really increase their prices in other countries: If Fincell learn about prices below US $ 360 also in the future, they will reconsider their policy as to sales in Spain!" [4] This is exactly the kind of strategy the firms are assumed to play in this paper. Another example is provided by the celebrated Lysine cartel. The cartel divided the market and had an elaborate punishment scheme in place: If a firm had sold more than its allocated share of the market at the end of the calendar year it would compensate the firms that were under budget by purchasing that quantity of lysine from them (see Connor 2001 and Hammond 2005). Clearly, such a punishment required detection of the individual sales, and the members of the cartel mistrusted each other on this point, see Connor (2001, p 12). Although the Lycine cartel rested on sales - not price - monotoring, the general principle is the same as in our model. A deviator caught in the act is punished.

[4] Official Journal (1985) §60

We focus on a trigger-strategy equilibrium, where in the collusive phase, firms collude on the best possible price, either the monopoly price, $p^m = u - t/2$ or some lower price. Observed deviations from collusion are punished with reversion to the one-shot Nash equilibrium for the rest of the game as suggested by Friedman (1971). Collusion on the price p can be sustained if the present value of collusive profits exceeds the expected profit from a deviation plus the present value of the expected continuation profit after a deviation. With probability η the deviation is observed and the continuation profit equals the present value of receiving Nash profits in all future. With probability $1-\eta$ the deviation is not observed and the continuation profits equal the present value of expected collusive profits. Letting π^N denote the expected profits of the Nash equilibrium (whether in mixed or pure strategies) the non-deviation constraint therefore becomes

$$\frac{1}{1-\delta}\pi(p) \geq \pi^d(p) + \eta\frac{\delta}{1-\delta}\pi^N + (1-\eta)\frac{\delta}{1-\delta}\pi(p). \tag{8}$$

When firms collude on p, their expected profit is $\pi(p) = p/2$ in all periods. If a firm deviates to a lower price, only informed consumers learn this before they visit the firm. The uninformed expect the firm to set p and half of them will visit the firm and get a nice surprise. The other half go to the other firm and will not observe the deviation. The optimal deviation price is

$$p^d = \begin{cases} \frac{1}{2}\left(p + \frac{t}{\phi}\right) & \text{if} \quad p \leq 2t + \frac{t}{\phi} \\ p - t & \text{if} \quad p > 2t + \frac{t}{\phi}\ . \end{cases} \tag{9}$$

The first expression in (9) applies when the optimal deviation does not capture the whole market. The deviation profit is

$$\pi^d(p) = \begin{cases} \frac{1}{8}\frac{(\phi p + t)^2}{\phi t} & \text{if} \quad p \leq 2t + \frac{t}{\phi} \\ (p-t)\frac{1+\phi}{2} & \text{if} \quad p > 2t + \frac{t}{\phi}\ . \end{cases} \tag{10}$$

Both expressions are increasing in ϕ when $p > t/\phi$. Hence, more can potentially be gained from a deviation when the market is more transparent on the consumer side.

If

$$\gamma \leq 2\phi, \tag{11}$$

then $\pi^d(p^m)$ is given by the first expression in (10) otherwise it is given by the second.

5 Differentiated markets

We now consider the case where product differentiation is relatively high so that (5) is not fulfilled and the one shot Nash equilibrium is in pure strategies.

Inserting the relevant expressions, we find that the non-deviation constraint for full collusion on the monopoly price (8) is fulfilled when firms are sufficiently patient, namely when

$$\delta \geq \hat{\delta} \equiv \begin{cases} \frac{\gamma}{\gamma+4\eta} & \text{if} \quad \gamma \leq 2\phi \\ \frac{\gamma-\phi}{(1+\eta/\phi)\gamma-\phi} & \text{if} \quad \gamma > 2\phi. \end{cases} \tag{12}$$

Clearly, $0 < \hat{\delta} < 1$. The first expression in (12) applies when the optimal deviation does not capture the whole market. Straightforward differentiation gives that $\hat{\delta}$ is increasing in the level of market transparency at the consumer side, ϕ, (since γ depends positively on ϕ) and decreasing in the level of market transparency on the producer side, η, regardless of whether $\gamma \lesseqgtr 2\phi$. More consumer transparency makes collusion more difficult, while more producer transparency makes it easier. Increasing transparency on the consumer side has two effects, a deviation becomes more profitable, but the ensuing punishment becomes harder as well. On balance, the first effect is the larger and therefore collusion becomes more difficult. Increasing transparency on the producer side makes it more likely that a deviation is detected, and this makes a deviation less profitable, thus collusion becomes eaiser.

The condition, $\gamma \leq 2\phi$, is fulfilled for all ϕ if $u/t < 5/2$ and fulfilled for $\phi \leq 1/\left(u/t - 5/2\right)$. In both cases, the extra profit from a large reduction in price is sufficiently small, that the optimal deviation does not capture the whole market. As is clear the condition is fulfilled for all ϕ if the transportation cost, t, reflecting the degree of product differentiation or "pickiness" of the consumers is sufficiently large.

Suppose then that the discount factor is lower than the crucial discount factor, $\hat{\delta}$. In this case, it is not possible for the firms to sustain full collusion on the monopoly price and the most favorable equilibrium from the point of view of the firms involves a collusive price which exactly makes the non-deviation constraint (8) fulfilled. This gives

$$p_c = \begin{cases} \left(1 + 4\eta \frac{\delta}{1-\delta}\right) p^N & \text{if} \quad \delta \leq \frac{\phi}{2\eta+\phi} \\ \left(1 + \frac{(1-\delta)\phi^2}{\phi-(\phi+\eta)\delta}\right) p^N & \text{if} \quad \delta > \frac{\phi}{2\eta+\phi}. \end{cases} \tag{13}$$

Clearly, p_c (and the associated profit) is decreasing in transparency on the consumer side and increasing in transparency on the producer side. Again the first line relates to the case where the optimal deviation does not capture the whole market.

Summing up these results we have

Proposition 1 *Suppose product differentiation is high, so (5) is not fulfilled. The lowest discount factor compatible with full collusion on the monopoly price is given by (12). It increases in consumer side transparency and decreases in producer side transparency. If the discount factor is so low that full collusion is impossible, then the highest price the firms are able to collude on is given by (13). It decreases in consumer side transparency and increases in producer side transparency.*

Proposition 1 considers changes in transparency on one side as independent of changes in the other side. But it may well be that measures influencing one side also influence the other side. Price comparison sites aimed at consumers may also be visited by producers and affect the transparency on the producer side as well. Similarly, news in the press may inform both sides. Suppose, therefore, that there are some common factor which influences both the fraction of informed consumers and the likelihood that a firm observes the other firm's price. Let $\alpha \in \mathbf{R}$ reflect the common factor. We will associate an increase in α with an increase in transparency so that the fraction of informed consumers $\phi = \phi(\alpha)$ and $\phi\prime(\alpha) > 0$ and the likelihood that a firm observes the other firm's price $\eta = \eta(\alpha)$, and $\eta\prime(\alpha) > 0$. Transparency on the two sides of the market affect the possiblities to collude differently and the net effect on collusion may be positive or negative. Increasing α affects the lowest discount factor compatible with full collusion with

$$\frac{d\widehat{\delta}}{d\alpha} = \frac{\partial\widehat{\delta}}{\partial\eta}\frac{\partial\eta}{\partial\alpha} + \frac{\partial\widehat{\delta}}{\partial\phi}\frac{\partial\phi}{\partial\alpha}.$$

Let e.g. $e_{\phi,\alpha} \equiv \frac{\partial\phi(\alpha)}{\partial\alpha}\alpha \Big/ \phi(\alpha)$ be the elasticity of ϕ wrt α. Then

$$\frac{d\widehat{\delta}}{d\alpha} > 0 \Leftrightarrow \frac{e_{\eta,\alpha}}{e_{\phi,\alpha}} < \begin{cases} 1 + 1/\gamma & \text{if} \quad \gamma \leq 2\phi \\ \frac{2\gamma^2 - 4\gamma\phi + 3\phi^2}{2\gamma(\gamma-\phi)} & \text{if} \quad \gamma > 2\phi. \end{cases} \tag{14}$$

The decisive feature is the elasticities and not the levels of transparency on the two sides. An increase in the common factor α is pro-competitive if the elasticity of ϕ wrt α is sufficiently large relative to the elasticity of η wrt α. The crucial cut off value depends on the gains from collusion and the transparency on the consumer side. When $\gamma \leq 2\phi$, so the optimal deviation does not capture the whole market (cf, (11)), it is a sufficient condition for fulfilling the the condition that the consumer side elasticity is larger than the producer side elasticity.

If full collusion on the monopoly price cannot be sustained, then effect on the best collusive price, p^c, from an increase in the common factor α is

$$\frac{dp^c}{d\alpha} = \frac{\partial p^c}{\partial\eta}\frac{\partial\eta}{\partial\alpha} + \frac{\partial p^c}{\partial\phi}\frac{\partial\phi}{\partial\alpha},$$

so

$$\frac{dp^c}{d\alpha} < 0 \Leftrightarrow \frac{e_{\eta,\alpha}}{e_{\phi,\alpha}} < \begin{cases} 1 + \frac{1-\delta}{4\eta\delta} & \text{if} \quad \delta \leq \frac{\phi}{2\eta+\phi} \\ \frac{1-\delta}{\delta} + \frac{\delta}{1-\delta}\frac{\eta^2}{\phi^2} + \eta - 2\frac{\eta}{\phi} & \text{if} \quad \delta > \frac{\phi}{2\eta+\phi}. \end{cases} \tag{15}$$

Again, an increase in the common factor is pro-competive if the consumer side elasticity is sufficiently higher than producer side elasticity.

Proposition 2 *Suppose product differentiation is high, so (5) is not fulfilled. An increase in a common factor α increasing transparency on both sides of the market, increases the lowest discount factor compatible with full collusion if ϕ is sufficiently more elastic than η wrt α, so that (14) is fulfilled. If the discount factor is so low that full collusion is impossible, then an increase in α lowers the collusive price if ϕ is sufficently more elastic than η wrt α, so that (15) is fulfilled*

When a common factor affects transparency on both sides, the competitive effect hinges on on which side of the market information spreads more easily, as measured by the relevant elasticities. Evidently, this depends on *how* information spreads - i.e. on the information technology. Suppose a consumer agency spends resources informing market participants about prices. We will now consider how this affects the market under two simple well known information technologies.

Suppose for example that the amount of money spent by some agency informing market participants constitutes the common factor α. The agency could be a government agency, a consumer agency or some other organization or entity. Suppose further that the probability the firms are informed about prices is increasing in the amounts spent and given by the concave function[5]

$$\eta(\alpha) = \frac{\alpha_0 + \alpha}{\alpha_0 + \alpha + h}, \tag{16}$$

where $h > 0$ represents the costliness of increasing the chance the firms learn the prices, and α_0 reflect that even if the consumer agency spends no resources, there will be some chance the firms learn each others' prices. If firms are easily informed, h is low, while the opposite is the case if h is high. The elasticity of η wrt α then becomes :

$$e_{\eta,\alpha} = \frac{\alpha h}{(\alpha_0 + \alpha)(\alpha_0 + \alpha + h)}.$$

Suppose, similarly that the probability a consumer is informed is given by the same kind of technology, but the costliness, $f > 0$, of informing a consumer may be different. The fraction of informed consumers is then

$$\phi(\alpha) = \frac{\alpha_0 + \alpha}{\alpha_0 + \alpha + f}, \text{ and } e_{\phi,\alpha} = \frac{\alpha f}{(\alpha_0 + \alpha)(\alpha_0 + \alpha + f)}.$$

Hence,

$$\frac{e_{\eta,\alpha}}{e_{\phi,\alpha}} = \frac{h}{f}\frac{\alpha_0 + \alpha + f}{\alpha_0 + \alpha + h} < 1.$$

iff $f > h$, i.e. if firms are less costly to inform. Suppose $\gamma \leq 2\phi$, (which is fulfilled if $\left(\frac{u}{t} - \frac{5}{2}\right)\phi < 1$) so that an optimal deviation captures the whole market. From (14) and (15) we then have that more resources spent by the consumer agency on information for sure is pro-competitive if $f > h$. If $\gamma \geq 2\phi$, then relative elasticity has to be less than a cut off value below one, and f has to be sufficiently much larger than h.

As an other example, consider Grossman and Shapiro's (1984) information technology (based on Butter (1977)). Here ads are placed in magazines.

[5] This function is for instance used in Coate (2004)

A given magazine's readership is the fraction r of the population. This equals the probabilty a consumer reads a given magazine. Furthermore, it is assumed that the probability that a given consumer sees an ad in one magazine is independent of the probability that she sees an ad in another magazine; that is, different magazines have independent readerships. Then if the agency places ads in α magazines, the probability that a given consumer will see none of these ads is $(1-r)^{\alpha}$. To avoid the special case, where the probability a consumer is informed is zero in the absence of the agency, we assume that there will be one magazine informing about prices even if the agency does not. To simplify, assume this magazine is not used by the agency. Hence the probability a consumer does not learn about prices is $(1-r)^{\alpha+1}$. Conversely, the probability she does learn about prices is therefore

$$\phi(\alpha) = 1 - (1-r)^{\alpha+1}. \tag{17}$$

The elasticity of ϕ wrt α is then

$$e_{\phi,\alpha} = \alpha \left(\ln(1-r)\right) \frac{(1-r)^{\alpha+1}}{(1-r)^{\alpha+1} - 1}. \tag{18}$$

Differentiating, we find

$$\frac{\partial e_{\phi,\alpha}}{\partial r} = \frac{\alpha}{(1-r)\left((1-r)^{\alpha+1} - 1\right)^2} \left(1 - (1-r)^{\alpha+1} + \ln(1-r)^{\alpha+1}\right)(1-r)^{\alpha+1}.$$

As $0 < r < 1$, this is negative if

$$\ln(1-r)^{\alpha+1} < -\left(1 - (1-r)^{\alpha+1}\right),$$

which is indeed true as $\ln 1 = 0$, $\ln'(1) = 1$, and $\ln''(x) < 0$. Hence $e_{\phi,\alpha}$ is decreasing in r.

Suppose that the probability a firm reads a given magazine is z. Then the probability that the firm is informed is $\eta(\alpha) = 1-(1-z)^{\alpha+1}$ and $e_{\eta,\alpha}$ is given by (18) with r replaced by z. If firms spend more resources than a consumer on collecting information, i.e. are more likely to read a given magazine than a consumer, then $z > r$, and since the elasticities are decreasing in r and z, we have

$$e_{\phi,\alpha} > e_{\eta,\alpha}.$$

Hence, if firms spend more ressources than consumers in achieving information, so that $z > r$, they are more likely to be informed and provided $\gamma \leq 2\phi$ then (14) and (15) are fulfilled and an increased effort by the consumer agency is pro-competitive. Again if $\gamma \geq 2\phi$, z has to be sufficiently much larger than r, for this to be the case.

Hence, for both considered information technologies, if firms are easier to inform and therefore better informed than consumers about prices (in the probabilistic sense), a larger effort by the agency informing the market is for sure pro-competitive if the market is sufficiently differentiated (such that the first lines in (14) and (15) are relevant). If the market is less differentiated, then the condition for this pro-competitive outcome is more stringent, then firms have to be sufficiently much more informed.

Summing up :

Proposition 3 *Suppose product differentiation is high, so (5) is not fulfilled. Consider an increase in a common factor α affecting transparency on both sides of the market, and $\gamma \geq 2\phi$. If the information techonogy is given by (16) or by (17) then a marginal increase in α is pro-competitive (both in terms of lowering the crucial discount factor for full collusion, and in lowering the best price firms can collude on if full collusion is impossible) if it is easier to inform firms, i.e. $f < h$ or $r < z$. If $\gamma < 2\phi$ the same is true if f (r) is sufficiently smaller than h (z).*

These results may appear counter-intuitive at first: If firms are more easy to inform, one could imagine that an increase in information is anti-competitive as transparency will be higher on the producer side. The crucial feature, however, is that the elasticities matter. If firms are easier to inform, they are better informed from the outset and an increase in information will have relatively less impact on the producer side of the market.

6 Almost homogeneous markets

Schultz (2005) showed that in the almost homogeneous market changes in transparency on the consumer side do not affect the scope for tacit collusion. Changes in price transparency therefore only affects competition through the producer side and since this effect is anti-competitive, the total effect is anti-competitive. For the sake of completeness, we derive the relevant crucial discunt factor here, when producer side transparency is included in the model. When product differentiation is very low (5) is fulfilled, the Nash equilibrium is in mixed strategies, and the optimal deviation price is given by the second part of the expression (9). The lowest discount factor compatible with full collusion is (using (8))

$$\bar{\delta} = \frac{\phi p^m - (1+\phi)\, t}{p^m (\eta + \phi) - 2\eta E\pi^N - (1+\phi)\, t}. \tag{19}$$

Clearly, $\partial\bar{\delta}/\partial\eta < 0$, so an increase in η makes collusion easier if indeed it is feasible. The effect of an increase in ϕ is

$$\frac{\partial\bar{\delta}}{\partial\phi} = \frac{\eta\left((p^m - t)\left(p^m - 2E\pi^N\right) + ((p^m - t)\,\phi - t)\, 2\frac{\partial E\pi^N}{\partial\phi}\right)}{\left((1+\phi)\, t - (\phi+\eta)\, p^m + 2\eta E\pi^N\right)^2}.$$

Unfortunately, the sign of $\frac{\partial\bar{\delta}}{\partial\phi}$ cannot directly be assessed for all relevant t as we have no closed form solution for $E\pi^N$. In the limit, as $t \to 0$, we get, using (6) and (7),

$$\lim_{t\to 0}\bar{\delta} = \frac{1}{1+\eta} \text{ and } \lim_{t\to 0}\frac{\partial\bar{\delta}}{\partial\phi} = 0 \tag{20}$$

When product differentiation is very low, the crucial discount factor allowing collusion on the monopoly price is independent of ϕ, the transparency of the consumer side. The reason is that in such a market, a firm which deviates by undercutting the other firm wil capture the whole *informed* part of the market, and earn the monopoly profit from this part of the market. The punishment (which is initiated with probability η) consists of loosing the firm's half share in monopoly profit from the informed part (as can be seen from (6)). Transparency on the consumer side, ϕ, changes the size of the informed market, but not the relation between the whole or the half of this part. Therefore ϕ has no effect on the no-deviation constraint. An increase in producer transparency, η, still facilitates collusion, since this increases the chance that the firm is punished for a deviation. Evidently, this implies that if a common factor affects transparency on both sides of the market, then the effect is unambigously anti-competitive.

7 Concluding remarks

Homogeneous and differentiated markets differ with respect to how one shoud assess the virtues of measures promoting price transparency that may affect both sides of the market. We have shown that in a homogeneous market, only the producer side effect matters and this effect is anti-competitive. In such markets, competition agencies or consumer agencies should not promote price transparency. In differentiated markets, however, the issue is more complicated. In the simple differentiated Hotelling market, the effects steming from the two sides counter each other. Under standard assumptions about information proliferation, the consumer side effect dominates and in such markets measures promoting price transparency are pro-competitive. The positive effects of the consumer side dominate over the negative effects of the producer side. Evidently, the better the measures can be targeted to the consumer side the better it is from a competition perspective. This may be hard, though. The results of this paper is somewhat relieving in this respect.

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