Transparency and Tacit Collusion

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Abstract

This paper investigates the effects on tacit collusion of increased market transparency on the consumer side as well as on the producer side of a market. Increasing market transparency on the consumer side, increases the benefits to a firm from undercutting the collusive price. It also decreases the punishment profit (whether the punishment is Nash-reversion or optimal punishment). The net effect is that collusion becomes harder to sustain. Increasing market transparency on the producer side facilitates collusion. When transparency is increased on both sides, the net effect is that collusion becomes harder to sustain.

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1 Introduction

The advent of the Internet has the potential of increasing market transparency in many markets. While consumers before had to spend considerable time searching many markets, there are now many well-established websites where price comparisons are available with a click on the mouse. Similarly, consumer agencies try to make markets more transparent in various ways, for instance though magazines and again through websites. Newspapers often have weekend sections, where a market is surveyed and prices compared. In these (and many other) cases market transparency is improved not by the firms selling in the market but by outside agents. The creation of the The European Internal Market was partly motivated by governments' belief (or hope?) that transaction costs would decrease and transparency would increase so competition intensified. This actualizes an old question in the competition policy debate: is market transparency good or bad? Does it promote competition and should a competition authority promote it or not? The purpose of this paper is to cast light on this question in a differentiated duopoly. In particular, we will investigate whether improved transparency will facilitate collusion or not. We will distinguish between improved transparency on the consumer side and on the producer side of the market.

In the competition policy debate, improved transparency is typically viewed as promoting competition if it affects the consumer side of the market. However, the arguments here often refer to a static setting. On the other hand, improved transparency on the producer side is typically thought to be anti-competitive, see for instance Kuhn and Vives (1995). If firms are uncertain about their competitors' prices, tacit collusion is harder to maintain. As originally noted by Stigler (1964) and Green and Porter (1984), when firms seek to collude, it is material that price undercutting is detected so that a punishment can be commenced. Taken alone this effect implies that increased transparency facilitates collusion. Improved transparency on the consumer side has different effects. In a static setting, the market becomes more competitive as the effective demand elasticity of a firm increases. However, the effects on collusion are ambiguous. The increased elasticity of demand makes it more tempting to undercut the other firm; this destabilizes collusion. On the other hand, a more severe punishment is possible in a transparent market. This facilitates collusion. The total effect on collusion is the net effect of these two forces. In the Hotelling model of the paper, the first effect dominates, so improving transparency on the consumer side makes tacit collusion more difficult to sustain.

Improved transparency thus affects the scope for collusion differently depending on which side of the market is affected. For the competition authorities, the crucial question is: "What is the net effect"? In the differentiated duopoly, the answer is clear: the consumer side effect dominates. On balance, improved transparency destabilizes collusion.

We identify market transparency on the consumer side with consumers' information about the prices charged by the firms in the market. Some consumers are informed about prices and some are not. Informed consumers are supposed to know both firms' prices, as they would if they access a web site comparing prices. The uninformed consumers have an expectation about the firm's price. In equilibrium, this expectation is correct. The uninformed consumers affects the amount of demand a firm can gain by lowering its price. Since only informed consumers will learn about a price change, the elasticity of demand facing a firm depends crucially on the share of consumers who know the firm's price, and therefore on the level of transparency.

In a market with high transparency on the consumer side, a firm can gain a relatively large market share by lowering its price. In such a market competition is intense and the static equilibrium price is low. However, the effect on tacit collusion in a repeated duopoly is more complicated. Tacit collusion requires that a potential deviation from the collusive path by one of the firms can be discouraged by a sufficiently hard punishment. We study the case where the punishment consists of reversion to the static Nash-equilibrium in all future. With Nash-punishments, the profit in the punishment phase decreases when market transparency increases. This makes the punishment phase more severe, and this effect pulls in the direction of making it easier for firms to collude on high prices. But there is a countervailing effect. The higher the market transparency, the larger market share can be gained by undercutting the other firm, increasing the temptation to deviate from the collusive price. In the model the second effect dominates the first, and the result is that increasing transparency makes collusion more difficult for firms to sustain. This shows up in two ways: first, the smallest discount factor necessary for sustaining collusion on the monopoly price is increasing in market transparency. Secondly, if the discount factor is too small for collusion on the monopoly price to be feasible, the maximal price (and therefore the profit) that the firms are able to sustain through tacit collusion is decreasing in the level of market transparency.

As is well known, if the discount factor is low, firms may do better by using harder punishment phases than reversion to the one-shot Nash equilibrium. We therefore also consider optimal symmetric stick and carrot equilibria. The result is the same: increasing transparency on the consumer side decreases the collusive price and profit.

Market transparency on the producer side is identified with the probability a deviation will be observed by the competitors. The smaller is this probability, the more tempting it is for a firm to cheat on the tacit collusion and undercut the other firm. By itself this makes collusion harder to sustain. A natural benchmark is when the transparency is equal on both sides of the market. We identify this situation with a case where the probability that a randomly chosen consumer is informed is equal to the probability that a firm is informed about the competitor's price. For this case we show, that increasing transparency on both sides of the market unambiguously destabilizes collusion. The lowest discount factor needed to uphold collusion on the monopoly price increases and the highest price, which can be upheld in tacit collusion when the discount factor is relatively low, decreases.

Market transparency is viewed differently in different countries and by different competition authorities. While the previous Danish competition act actively tried to promote transparency in order to increase competitiveness (see Albæk, Møllgaard and Overgaard (1994)), the Danish government now acknowledges that, although transparency may be good in so far as it increases consumers' information, it may help firms collude if it increases firms' information, see e.g. Erhvervspolitiken (1999). The EU commission seems to have a mixed view. Kuhn and Vives (1995) conclude that the Commission mostly found increased transparency in the form of price-announcements by firms as anti-competitive. However, the internal European market as well as the single European currency has often been seen as adding to transparency and therefore competitiveness.

Market transparency has been analyzed from different angles in the literature. The literature on advertising can be seen as contributing to understanding market transparency. Notice, however that in this case the firms participating in the market actively affects market transparency. In this sense there is a difference to the present paper, where we consider the case where market transparency if affected by outside agents. The literature on advertising, see e.g. Bester and Petrakis (1995), tend to argue that increased advertising leads to lower prices. This is also the result of the search literature. Lowering search costs increases search and this intensifies competition; see Burdett and Judd (1993). Anderson and Renault (1999) study price competition when consumers have to search for prices and product characteristics. They show that market prices rise with search costs. On the other hand, cartel theory stemming back to Stigler (1964), Green-Porter (1984) and others, see Tirole (1988) for an overview, has pointed to the anti-competitive effects of increased transparency for the reasons described above

Nilsson (1999) concentrates on the consumer side. He considers tacit collusion in a repeated search model a la Burdett and Judd (1993). Here lowering search cost lowers the price in a one shot equilibrium, but facilitates collusion in the repeated game. In Nilsson's model, most of the consumers decide whether to search taking into account the expected benefits from searching, while a fraction of the consumers always search. The majority of consumers therefore stop searching if firms set the same prices. This happens if the firms collude on a high price. Since most consumers do not search in this case, a firm, which undercuts the other firm, will only achieve a relatively small increase in demand. This facilitates collusion. In the punishment phase of the collusive equilibrium, however, firms do not set the same price, (they play a mixed strategy) therefore search occurs and increasing transparency through lowering search costs intensifies competition in this phase. Thus increasing transparency increases search in the punishment phase but not in the collusive phase, as a result increasing transparency facilitates collusion. In my model, on the contrary, increasing transparency increases the information level of consumers in both phases and the result is therefore different.

Møllgaard and Overgaard (2000) also study the consumer side. They identify transparency with the ability of consumers to compare the characteristics of goods and services. They study an adapted repeated version of Singh and Vives (1984) model of a differentiated duopoly. They interpret the substitutability of the goods in the consumers' utility functions as a measure of transparency. Increased transparency therefore makes consumers switch producer more easily. In collusive trigger-strategy equilibria, this increases the temptation to undercut the other firm - since more demand will be gained. However, it may also make the punishment phase of the equilibrium more severe. An "optimal degree" of transparency therefore exists. Their paper - as well as the present - is related to the literature on stability of collusion in differentiated markets. See, for example, Deneckere (1983), Chang (1991), Ross (1992) and Häckner (1995). These authors show that as products become more substitutable, deviation becomes increasingly attractive. Although the punishment phase also becomes more severe, the first effect dominates and collusion is harder to maintain. Compared with the present paper, the difference is that this literature compares the effect of changing preferences. We let preferences and product characteristics remain fixed and investigate the effect of price transparency.

Baye and Morgan (2000) study the effect of web sites in homogeneous product markets in a static model. The site-owner maximizes profit and charges firms' a fee for advertising their price on the site and consumers a fee for seeing the listings. In equilibrium, there is price dispersion in the product market. They show that the information site has ambiguous welfare effects. Part of the reason is that advertising fees exceed the socially optimal level.

The organization of the paper is the following. Section 2 introduces a simple Hotelling market. Nash equilibrium is characterized in section 3, while section 4 deals with monopoly pricing. Sections 5 and 6 study the effect of transparency on the consumer side on tacit collusion, with Nash punishments and optimal punishments respectively. Section 7 includes the effect of transparency on the producer side. Section 8 concludes.

2 A Hotelling market

Consider a Hotelling market with a continuum of consumers. Consumer x is located at $x \in [0,1]$. Each consumer either buys one unit of the (differentiated) good or does not buy. There are 2 firms, located at 0 and 1 respectively. If firms charge prices p_0 and p_1, consumer x gets utility $u - p_0 - tx$ from buying one unit from firm 0 and $u - p_1 - t(1-x)$ from buying a unit from firm 1. The parameter $t > 0$ is the transportation cost. A consumer, who knows the prices of the firms is therefore indifferent between buying from 0 and 1 if

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

The market is not completely transparent, so some consumers are not informed about the firms' prices. There are two different *information types* of consumers: a fraction ϕ are informed about both firms' prices, while a fraction $(1-\phi)$ are uninformed. The variable ϕ is our measure of market transparency, the higher is ϕ, the more transparent is the market. We conceive of the informed consumers as having easy acces to the pricing information, perhaps through an internet site. Both information types of consumers are supposed to be uniformly distributed on locations. In principle one could of course also imagine that some consumers are only informed about one of the firms' price. This would just complicate a few formulas below, so we will go for

All consumers know the locations of the firms, regardless of whether they are informed about the firms' prices or not. A consumer, who is uninformed about firm $i's$ price has an *expectation* p_i^e of firm $i's$ price. For this consumer, the *expected* utility from buying form firm i is $u - p_i^e - tx$. An uninformed consumer, is indifferent between buying form the two firms, if she is located at

$$x = x(p_0^e, p_1^e) \equiv \frac{1}{2} + \frac{p_1^e - p_0^e}{2t}$$

If the consumer has a smaller x, she visits firm i, if the consumer has a larger x she visits firm j. A consumer can only visit one firm in a period. Hence, it is not possible for uninformed consumers to visit the firms in a sequence. To be concrete we assume that the time line is as follows. First consumers form expectations, second firms set prices. Some consumers become informed about the prices, some do not. Based either on their knowledge or expectations about prices consumers decide which firm to go to - if any. A consumer can only go to one firm. Then transactions take place.

We can now find the demand for firm $0's$ product

$$D(p_0, p_1, p_0^e, p_1^e, \phi) = \phi x(p_0, p_1) + (1 - \phi)\, x(p_0^e, p_1^e) \tag{2}$$

We assume that the market is covered, so the demand for firm 1's product is $1 - D(p_0, p_1, p_0^e, p_1^e)$.

The timing of the game is as follows, first consumers form expectations about prices, p_0^e, p_1^e, firms set prices, p_0, p_1, which are observed by the informed consumers only. Then consumers decide which firm to visit and transactions are carried out. The firms' prices are set simultaneously. At the price setting stage, the firms take the expected prices as given. The result will depend on the expectations, equilibrium prices will be $(p_0(p_0^e, p_1^e), p_1(p_0^e, p_1^e))$. We will assume that expectations are rational, so in equilibrium $p_0^e = p_0(p_0^e, p_1^e)$, and

$p_1^e = p_1(p_0^e, p_1^e)$. Rational expectations ensure that in equilibrium, there will be no consumers, who are surprised by a high price of a firm, and who would consequently like to go to the other firm after first visiting a firm.

3 Static Nash equilibrium

We first concentrate on the one period Nash equilibrium. For simplicity we disregard costs, so firm $0's$ profit is $\pi_0 = p_0 D(p_0, p_1, p_0^e, p_1^e)$. Each firm takes the price expectations as well as the other firm's price as given and seek to maximize profits. Firm 0's problem is

$$\text{Given } p_0^e, p_1^e, p_1 \ \max_{p_0} \ p_0 D(p_0, p_1, p_0^e, p_1^e).$$

The first order condition for maximum for firm 0 is

$$D(p_0, p_1, p_0^e, p_1^e) + p_0 \left(\phi_b \frac{\partial x(p_0, p_1)}{\partial p_0} + \phi_i \frac{\partial x(p_0, p_1^e)}{\partial p_0} \right) = 0. \tag{3}$$

Using rational expectations, $p_0^e = p_0$ and $p_1^e = p_1$, so (3) reduces to

$$x(p_0, p_1) + p_0 \phi \frac{\partial x(p_0, p_1)}{\partial p_0} = 0. \tag{4}$$

Firm 0 chooses a price so that the elasticity of demand equals $-\frac{1}{\phi}$. Assuming the market is covered, so that all consumers buy, then in a symmetric equilibrium, $x(p_0, p_1) = 1/2$. Using equation (1), we then get that the Nash equilibrium price $p^N(\phi)$ is given by

$$p^N(\phi) = \frac{t}{\phi},$$

which is clearly decreasing in ϕ. Thus more transparency increases competition and lowers the Nash-equilibrium price. The intuition is clear from the rewritten first order condition (4). When a firm decreases its price, this is only noticed by the informed consumers, so they are the only to increase demand. The larger is the fraction of informed consumers, ϕ, the larger is the demand effect from lowering price and the more intense competition is among the firms. It is straightforward to check that the second order condition for maximum is fulfilled. The assumption that the market is covered takes that the consumer in the middle is willing to buy at p^N, this is fulfilled if $u - p^N - t/2 \geq 0$ or

$$\phi \geq \frac{t}{2u - t}. \tag{5}$$

So, market transparency should not be too low. If (5) is not fulfilled, the transparency is so low that there effectively is no competition in the market. Even in a Nash equilibrium, the firms are not competing about the consumers. In the sequel we will assume that (5) is fulfilled.

The Nash-equilibrium profit, π^N, is

$$\pi^N = \frac{t}{2\phi}.$$

Since p^N is decreasing in ϕ, so is π^N. This also shows, that if we consider the one shot game, the firms - jointly − have no interest in promoting market transparency, actually they have the opposite interest, since transparency intensifies competition.

We may notice that the Nash equilibrium price is decreasing in transparency even though we do not make the special assumption of a Hotelling market. More generally, assume the demand facing firm 0 is given by equation (2). From the first order condition (3) we can find the effect on firm zero's best reply price from an increase in transparency. Straightforward implicit differentiation gives that

$$\frac{dp_0}{d\phi} = \frac{-p_0 \frac{\partial x(p_0, p_1)}{\partial p_0}}{\pi_{00}} < 0,$$

where π_{00} is the second derivative of the profit function, which is negative by the second order condition. This imply that firm zero's reaction function is moved inwards when ϕ increases. As firm 1 is in a similar situation, its reaction function also moves inwards. Consequently, the Nash equilibrium price falls. As the Nash equilibrium price is lower than the monopoly price, this imply that the Nash equilibrium profit falls if the symmetric profit $(\pi(p, p))$ is quasi-concave.

4 Monopoly pricing

Now consider the case where firms collude in order to share the monopoly profit. Whether this imply selling to all consumers or not depends on the size of the transportation cost t. and the market transparency. If t is very high, it is most profitable to set a price so high, that the consumers in the middle will not buy. If t is low and ϕ not too small, all consumers are served. We will consider this case, where competition is most intense.

If firms sell to all consumers, so the market is covered, the profit maximizing price, p^m, makes consumer $x = 1/2$ indifferent between buying or not. Hence,

$$p^m = u - t/2 \tag{6}$$

and in a rational expectations equilibrium where $p^e = p^m$, firms sell to both informed and uninformed consumers, and the profit to each firm is

$$\pi^m = \frac{(u - t/2)}{2} \tag{7}$$

If they choose partial market coverage, they sell to different segments of the market, consumers located to the left goes to firm 0, consumers to the right to firm 1. Consider firm 0, its marginal informed consumer has an x given by $u - p_0 - tx = 0$, i.e. $x = (u - p_0)/t$. A fraction ϕ is informed about firm $0's$ price, a fraction $1 - \phi$ rely on their expectation of the price. The optimal price therefore maximizes $\left(\phi \frac{u-p}{t} + (1-\phi)\frac{u-p^e}{t}\right) p$. The first order condition for maximum is

$$-\phi \frac{p}{t} + \left(\phi \frac{u-p}{t} + (1-\phi)\frac{u-p^e}{t}\right) = 0$$

Using rational expectations $p^e = p$, gives the solution

$$\tilde{p}^m = \frac{u}{(1+\phi)}$$

Notice that also the monopoly price is decreasing in market transparency when the market is not covered. The reason is that the more transparent the market is, the more demand the monopolist gains by lowering the price. It is easy to check that under assumption (5), the demand facing firm 0 at $\tilde{p}^m > 1/2$. Hence, the firms choose full marked coverage, and the monopoly price is given by (6).

5 Consumer side transparency and collusion

Now we consider a repeated game. There are infinitely many periods, $\tau = 0, ..., \infty$. In each period the market is as described above. Firms seek to maximize the discounted sum of 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 his location) is the same in all periods. Hence, for instance a consumer who is uninformed about firm $0's$ price, is uninformed before trading in all periods. Clearly, if the consumer buys from firm 0, she learns firm $0's$ price ex post, if she does not buy from firm 0, she will not learn the price.

We will study a rational expectations equilibrium, where consumers' price expectations depend on the firms' past prices. We focus on a trigger-strategy equilibrium, where in the collusive phase, firms collude on the best possible price. Deviations from collusion are punished with reversion to the one-shot Nash equilibrium for the rest of the game as suggested by Friedman (1971).

As is well known since the work of Abreu (1983) there may be more harsh punishment phases, on the other hand one may doubt the credibility of very hard punishment (see e.g. Farrell and Maskin (1994)). Since the theory does not provide clear guidance, we will consider both cases. We first consider Nash punishments.

Consider the following trigger-strategy equilibrium. Uninformed consumers expect a collusive price p in period 0 and in all future periods as long as they have only seen this collusive price. If they once encounter a different price, they expect the Nash equilibrium price from both firms in all future. As we will see these expectations are rational in equilibrium. The collusive price may be the monopoly price p^m or some smaller price, we will investigate both cases.

Assume that the firms are collude on the price, p. If a firm in one period chooses another price, then both firms choose the Nash equilibrium price $p^N(\phi)$ in all future.

If a firm chooses p in all periods it earns $\pi(p) = \frac{p}{2}$ in all periods. If it deviates from collusive play, the best deviation price maximizes its one period profit. This price maximizes

$$p'\left(\phi\left(\frac{1}{2}+\frac{p-p'}{2t}\right)+(1-\phi)\frac{1}{2}\right).$$

Notice, that only a fraction ϕ will learn that the firm has lowered its price before they decide to visit the firm. The rest $1-\phi$ expects the firm to set p. Half of these consumers will visit the firm and get a nice surprise and will not decline to buy from the firm. The other half will not observe the deviation, as they buy from the other firm. The optimal deviation price is given by

$$p^d = \frac{1}{2}\left(p + \frac{t}{\phi}\right), \tag{8}$$

which is decreasing in ϕ and less than the collusive price p, when $p > t/\phi = p^N$. The more transparent the market is, the more demand is captured by a price decrease, and the lower is the optimal price.

The associated profit is

$$\pi^d(p) = \frac{1}{8}\frac{(\phi p + t)^2}{\phi t}, \tag{9}$$

which is increasing in ϕ when $p > t/\phi$. Hence, the more transparent the market, the more can potentially be gained from deviating from collusive play. Clearly, this effect by itself makes collusion harder to sustain.

In the next period a punishment phase will start. Say that firm 0 was the deviator. Uninformed consumers, who bought from firm 1 did not learn that firm 0 deviated. They expect that both firms set p^m in the first period of the punishment. They will therefore go to firm 1 again and get a nice surprise. All consumers who bought at firm 0 know that a deviation took place, so they will expect p^N. The informed consumers will of course know the actual prices before trading. The demand facing firm 1 in the period after the deviation by firm 0 is therefore

$$(1-\phi)\frac{1}{2} + \phi\left(\frac{1}{2} + \frac{p^N - p}{2t}\right)$$

and the static best reply is p^N. Similarly, the static best reply for firm 0 is p^N. In all subsequent periods of the punishment phase, all consumers expect both firms to set p^N, and the static Nash equilibrium is p^N. This shows that the punishment phase is subgame perfect.

Suppose now that the firms seek to collude on the monopoly price p^m. In this case they each earn the monopoly profit per firm $\pi^m = p^m/2$ in each period. Collusion can be sustained if the present value of monopoly profits exceeds the deviation profit plus the present value of the punishment profits, i.e., if

$$\frac{1}{1-\delta}\pi^m \geq \pi^d(p^m) + \frac{\delta}{1-\delta}\pi^N \tag{10}$$

Inserting the relevant expressions, we see that this is fulfilled when firms are sufficiently patient, namely when

$$\delta \geq \bar{\delta} \equiv \frac{2\phi u - t\phi - 2t}{2\phi u - t\phi + 6t} = 1 - \frac{8t}{2\phi u - t\phi + 6t}.$$

As may readily be checked $0 < \bar{\delta} < 1$. Clearly, $\bar{\delta}$ is increasing in the market transparency. In this sense full collusion on the monopoly price is more difficult to sustain when the market is more transparent.

Suppose $\delta < \bar{\delta}$, then collusion on the monopoly price cannot be sustained. The most favorable equilibrium from the point of view of the firms involves a collusive price which exactly makes the non-deviation constraint fulfilled, i.e. the price solves

$$\frac{1}{1-\delta}\pi(p) = \pi^d(p) + \frac{\delta}{1-\delta}\pi^N \tag{11}$$

Inserting the relevant expressions, one finds two solutions, the one shot Nash equilibrium price $p^N(\phi) = t/\phi$ and

$$p(\delta, \phi) = \frac{1+3\delta}{(1-\delta)}\frac{t}{\phi}, \tag{12}$$

which yields the highest profit possible given the constraint (11) should be fulfilled. Clearly, $p(\delta, \phi)$ is decreasing in the market transparency and so is the profit (which equals $p(\delta, \phi)/2$). The more transparent the market is, the less is the maximal price and profit which can be realized through tacit collusion. Hence, the model gives the unambiguous result that increasing transparency is beneficial for consumers and detrimental to firms. This result is, however, a net result of two opposing forces. First, the deviation profit is higher in a more transparent market (equation (9)), this makes collusion harder to sustain. On the other hand, the Nash equilibrium profit is smaller in a more transparent market, which makes the punishment harder. Hence, there are two countervailing effects. On balance, the effect on the deviation profit is larger, and therefore the net result is that increasing market transparency makes collusion harder to sustain and hence the collusive price and profit smaller.

In the more general case, where demand is just given by equation (2) one readily finds that the deviation profit is increasing in market transparency if the firms coordinate on the monopoly profit. In this case the deviation profit equals

$$\pi^d = \max_p \; p\left(\phi x(p, p^m) + (1-\phi)x(p^m, p^m)\right)$$

Using the envelope theorem one gets

$$\frac{d\pi^d}{d\phi} = p\left(x(p, p^m) - x(p^m, p^m)\right) > 0.$$

However, it is not possible in general to assess whether this increased deviation profit is offset by the increased punishment associated with the smaller Nash equilibrium profit.

6 Optimal punishments

In this section we briefly consider equilibria with optimal symmetric punishment phases. When the discount factor is sufficiently high, reversal to the one shot Nash equilibrium is sufficient for sustaining the monopoly price. For lower discount factors this is not possible, and as is well known, the firms may realize higher profits in the normal phase of the equilibrium by using harder punishment phases. In principle, there are no bounds below the prices the firms charge. They could even start giving money to customers by charging a negative price. Since we disregard unit cost, the price in the model should be considered as a net-of-cost price. A negative price does therefore not necessarily imply a negative gross price. In order to avoid complications in the formulas from negative prices, we will however assume that the parameters of the model are such that this punishment price is positive in the model. Implicitly, this means that we are studying the case of quite low discount factors. Remember, that if the discount factor is zero, the worst "punishment" consists of the Nash equilibrium price and profit in each period. As the discount factor increases from zero, lower prices can be sustained, for even higher discount factors negative prices may be sustained. From Abreu (1988) it is known that any equilibrium payoff can be realized in an equilibrium with simple strategies, consisting of a normal phase and a punishment phase. We will study equilibria where the punishment only lasts one period - stick and carrot equilibria (cf Abreu (1986)). As the game is symmetric, we look at symmetric equilibria.

As it turns out, the collusive price may be quite high and in order to make sure that the market is covered, the following assumption - which is stronger than (5) is assumed in this section

$$\phi > \frac{4t}{2u - t}. \tag{13}$$

Suppose both firms set p, the best deviation is to p^d as given in (8). Notice, that if $p < p^N = t/\phi$, the deviation price is *higher* than the original price. In this case the uninformed consumers get an unpleasant surprise and they would have preferred to go to the other firm if they had been aware of the higher price. However, the deviation price is still below the Nash equilibrium price, and all consumers prefer to buy at this price rather than not buying. The associated deviation profit is given by (9).

Consider the following prescription for "stick and carrot "strategies. Let p be a (high) normal price and q a (low) punishment price. Both firms set p in the first period and set p in each period where p - or q - were set by both firms in the previous period. If a firm deviates from this prescription, both firms set q for one period and then return to setting p. If a firm deviates from this, they both set q for one period and then return to setting p. Consumers expectations mirror this, they start by expecting $p^e = p$. If in the previous period prices were p or q they expect $p^e = p$, otherwise they expect $p^e = q$.

With these strategies a deviation from the normal phase (or the punishment phase) is punished by one time choosing a bad price, q, and then returning to the normal phase. The normal phase profit is $\pi(p) = p/2$. The equilibrium is characterized by the following incentive equations.

$$\frac{1}{1-\delta}\pi(p) \geq \pi^d(p) + \delta\left(\pi(q) + \frac{\delta}{1-\delta}\pi(p)\right) \tag{14}$$

The present value of choosing the normal phase price p should equal the deviation profit plus the present value of being punished for a period and then returning to the normal phase. A firm may deviate from the punishment This will be punished by a restart of the punishment phase. It is not attractive to deviate in the one period the punishment phase lasts if

$$\pi(q) + \frac{\delta}{1-\delta}\pi(p) \geq \pi^d(q) + \delta\left(\pi(q) + \frac{\delta}{1-\delta}\pi(p)\right) \tag{15}$$

which we can rewrite

$$(1-\delta)\,\pi(q) + \delta\pi(p) \geq \pi^d(q) \tag{16}$$

In the optimal equilibrium (14) and (16) are both fulfilled with equality. Inserting gives two equations in two unknowns

$$\begin{aligned}\frac{1}{1-\delta}\frac{p}{2} &= \frac{1}{8}\frac{(\phi p+t)^2}{\phi t}+\delta\left(\frac{q}{2}+\frac{\delta}{1-\delta}\frac{p}{2}\right)\\(1-\delta)\frac{q}{2}+\delta\frac{p}{2} &= \frac{1}{8}\frac{(\phi q+t)^2}{\phi t}\end{aligned}$$

With two pairs of solutions, $p = q = t/\phi = p^N$ and

$$p = (1+8\delta)\frac{t}{\phi} \text{ and } q = (1-8\delta)\frac{t}{\phi} \tag{17}$$

Clearly, q is only positive if $\delta < 1/8$. Under assumption (13), the consumer in the middle is willing to buy at $p = (1+8\delta)\frac{t}{\phi}$. It is easy to check that p is higher than the collusive price which can be sustained by a punishment phase consisting of reversion to the one shot Nash equilibrium given by (12) when $0 < \delta < 1/2$.

It is clear from (17) that the collusive profit with optimal stick and carrot punishments is decreasing in ϕ.

7 Transparency on the producer side

So far we have concentrated on market transparency on the consumer side. In this section we include transparency on the producer side of the market. Just as is the case with consumers, we now assume that a firm only observe the other firm's price with some probability, $\eta \in]0,1[$, which may or may not be equal to ϕ. The fact that firms may not observe each other's price can affect the possibility of maintaining tacit collusion. A firm may deviate in a period and the other firm may not see that it deviated. However, the other firm will find that its demand decreases and in this way it will be able to infer that the other firm deviated. Hence, as is well known from the literature, introducing imperfect monitoring per se does not change the possibility of collusion. This is due to the assumption that the market size is fixed and known to both firms. In this section we will therefore assume that the market size is stochastic. If a firm experiences that the demand for its product falls and it does not observe the price of the other firm, it cannot know for sure whether the decline in demand was caused by a bad shock to the market or by a low price set by the other firm.

To be specific, we now assume that in a period, each consumer demands $s \geq 0$ units or zero units of the good, where s is a stochastic variable. Otherwise the description of the consumers is as before. In particular a consumer only visits one firm. This implies that the demand functions facing the firms are as previously. For for instance the demand facing firm 0 from consumers who are aware of both firms prices is given by

$$x(p_0, p_1, s) \equiv s\left(\frac{1}{2} + \frac{p_1 - p_0}{2t}\right)$$

and so forth. The variable s represents the size of the market. We assume that s is distributed identically and independently in all periods according to the distribution function $\psi(s)$, and the expected size of the market is one, $\int_s s\psi(s) = 1$. We also assume that $[0, 1]$ is contained in the support of ψ. Hence any decrease in demand is possible for a firm. The firms do not learn s before choosing prices. At this stage, firms therefore expect the market to have size one. First firms choose prices, then the market size s is realized. Firms are assumed to maximize expected profits. With this formulation the formulas for expected profits are equal to the profit expressions above, for instance π^m is still given by (7), the deviation profit is given by (9) etc.

We will restrict ourselves to look at an optimal trigger strategy equilibrium where the punishment phase consists of reversion to the one shot Nash equilibrium. There can be different kinds of such equilibria according to how the punishment phase is triggered. When a firm is faced with a very low demand in a period where it does not observe the price of the other firm, it may have reason to believe that the other firm deviated and wish to initiate the punishment phase. This is the way Green and Porter (1984) construct an equilibrium. In their work there are no possibilities for the firms for observing each other's prices. In our set up firms do observe each other's prices (with some probability). We will focus on equilibria where punishments are only initiated if a firm actually sees that the other firm deviated. Hence, the equilibrium strategies are as follows. In the first period the firms both choose the collusive price p. They continue to do so until a firm chooses another price *and this is observed by the other firm.* In this section we will assume that if the deviation is observed by the other firm, this fact *becomes common knowledge among the firms.* One could imagine that with some probability a newspaper writes about the event, in this case both firms are aware that the other firm observed the deviation. Hence, at the start of the next period the deviating firm knows whether its deviation was observed or not. If the deviation was observed, both firms choose the Nash equilibrium price for all subsequent periods. Consumers' expectations mirror this. They expect both firms to choose the collusive price, until they observe a deviation, which the other firm learns. After that they expect the one shot Nash equilibrium period for all subsequent periods.

The no-deviation constraint, if firms collude on the price p, becomes

$$\frac{1}{1-\delta}\pi(p) \geq \pi^d(p) + \eta\frac{\delta}{1-\delta}\pi^N + (1-\eta)\frac{\delta}{1-\delta}\pi(p) \tag{18}$$

Inserting the relevant expressions yields that the firms are able to collude on the monopoly price p^m if the discount factor fulfills

$$\delta \geq \widehat{\delta} \equiv \frac{2\phi u - \phi t - 2t}{2\phi u - \phi t - 2t + 8t\eta} \tag{19}$$

It is readily seen that $\widehat{\delta}$ is increasing in ϕ (as in the previous section) and decreasing in η. This is as expected, the smaller the likelihood that a defection is detected, the harder is collusion to sustain. This shows up in a lower smallest discount factor necessary for sustaining collusion on the monopoly price. If the discount factor is below $\widehat{\delta}$, we find by inserting in (18) that the highest price the firms are able to sustain is

$$p = \frac{(1-\delta+4\delta\eta)}{(1-\delta)}\frac{t}{\phi} \tag{20}$$

which is increasing in η and decreasing in ϕ.

The effect of an equal rise in transparency equal to Δ on both sides can be found from (20). In this case the change in the collusive price is

$$dp \equiv \frac{\partial p}{\partial \eta}\Delta + \frac{\partial p}{\partial \phi}\Delta < 0 \text{ if and only if } \phi - \eta < \frac{1-\delta}{4\delta} \tag{21}$$

A general rise in transparency lowers the collusive price if and only if producer transparency is not too small compared with consumer transparency, otherwise the collusive price is increased. This is intuitive: if consumer transparency is very high, and producer transparency very low, then the effect of increasing general transparency is most important on the producer side, and this is the side where collusion is facilitated by an increase in transparency.

A natural benchmark case to consider is the case where the information flows equally easily on both sides of the market. In this case the probability that a randomly chosen consumer knows prices, ϕ, equals the probability that a firm knows the price of the other firm, η. In this case, where $\eta = \phi$, the *transparency is the same on both sides of the market.* For this case we get

$$\widehat{\delta}\,|_{\eta=\phi} \equiv \frac{2\phi u - \phi t - 2t}{2\phi u + 7\phi t - 2t} \tag{22}$$

which is increasing in ϕ. Furthermore (20) gives,

$$p\,|_{\eta=\phi} = \frac{4t\delta}{1-\delta} + \frac{t}{\phi} \tag{23}$$

which is decreasing in ϕ. We conclude that if transparency is equal on both sides of the market, improving transparency makes collusion harder. Hence increasing transparency is uambiguously good for consumers and bad for firms.

8 Concluding remarks

This paper has analyzed the effect on tacit collusion from an increase in market transparency. It is important to distinguish between transparency on the consumer side and on the producer side. The first part of the paper focused on the consumer side. In a static equilibrium, increased transparency unambiguously increase competition and lowers prices and profits while consumers' surplus increase. When firms meet repeatedly in the market and seek to collude tacitly, there are two effects. Increasing transparency on the consumer side increases the temptation to undercut the other firm in the most collusive equilibrium, while it makes the punishment harder in the trigger strategy equilibrium with Nash punishment. The two effects draw in different directions, but the first effect dominates, increasing transparency makes collusion more difficult and is pro-competitive. This result also holds true for the equilibrium with optimal punishments. In the model of the paper the conclusion is unambiguous: more transparency on the consumer side is pro-competitive. Transparency in the producer side, have an opposite effect. The more transparent the market, the more likely defections from collusive play are detected and this facilitates collusion. In a simple equilibrium with Nash punishments the consumer side effect dominates. Increasing transparency in both sides of the market destabilizes collusion.

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