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Economics Letters 93 (2006) 398–404

economics letters

www.elsevier.com/locate/econbase

Transparency and prices with imperfect substitutes

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Received 24 August 2005; received in revised form 23 May 2006; accepted 27 June 2006
Available online 27 October 2006

Abstract

We show that an increase in consumer transparency may increase prices if goods are imperfect substitutes. If the consumers have more information about the goods that are available and about corresponding prices they will increase their demand. The effect of this on prices may override the competition enhancing effect of transparency.
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Keywords: Transparency; Demand effect; Competition effect

JEL classification: D40; L10

1. Introduction

It is often suggested that transparency will increase competition, reduce prices, and increase consumer surplus. In this paper we illustrate a potential caveat to this argument. A rise in transparency increases consumer awareness about the different products available and about their prices. If goods are imperfect substitutes this may increase total demand and lead to higher prices.[2] Of course, this demand effect

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[2] Others have studied the potential impact of transparency on tacit collusion (e.g., Schultz, 2005, Møllgaard and Overgaard, 2000, Nilsson, 1999). Our analysis is purely based on a static analysis, a feature it shares with Janssen and Moraga (2000) and Schultz (2004). In the latter paper transparency covers not only awareness about prices but also about the exact product characteristics.

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doi:10.1016/j.econlet.2006.06.003

disappears if goods are perfect substitutes. In this case we are left with the competition effect of transparency: competition intensifies and prices decrease when buyers become better informed.

We employ a static model in which there are two types of buyers. One type of buyer is perfectly informed about all products and prices offered by different sellers; the other type is only informed about the product and price of one seller and is restricted to buy from this particular seller.[3] The fraction of buyers that is perfectly informed is an exogenous parameter which we take as a measure for the level of transparency in the market.

2. Model

Consider a market with n producers and continuum of consumers of size 1. Consumers' utility functions are of the form

$$u(x_1,\ldots,x_n,M) = \sum_{i=1}^{n} \left\{ x_i - x_i^2 - 2\sigma \sum_{j>i} x_i x_j \right\} + M \tag{1}$$

where x_i is the amount of good i ($=1,\ldots, n$), M is a composite good of all the other products in the economy, and σ indicates the degree to which goods from different producers are substitutes. Let a fraction τ of consumers be aware of all the n products in this market. They maximize the utility function above subject to a budget constraint. It is routine to verify that the inverse demand functions of these informed customers are of the form

$$p_k^I(x_k, x_{-k}) = 1 - 2x_k - 2\sigma \sum_{l \neq k} x_l$$

Of the $(1-\tau)$ other consumers, a fraction $\frac{1}{n}$ knows only of product i and is not aware of any other product. Their utility function is $u(x_i, M) = x_i - x_i^2 + M$. The inverse demand function of an uninformed consumer equals

$$p_i^U(x_i) = 1 - 2x_i$$

We say that transparency increases in this market as the fraction of people τ who are aware of all products increases.

Now we analyze the equilibrium, that is, the prices that clear the market. Let x_j denote total output of firm j. Further, let x_j^U (x_j^I) denote firm j's output per head of uninformed (informed) customer. Although there are asymmetric equilibria in which some firms only produce for their "own" captive consumers,[4] we focus here on equilibria in which all firms produce for both informed and uninformed consumers, i.e., $x_j^U > 0$ and $x_j^I > 0$. Since there are τ informed customers and $\frac{1-\tau}{n}$ uninformed customers who only know

[3] This is similar to, though not the same as Varian's (1980) assumption that the uninformed are randomly allocated to one of the sellers.

[4] See the working paper version of this paper (at http://greywww.kub.nl:2080/grey.les/ center/2002/7.html) for a characterization of these equilibria.

firm j's product, the following relationship holds between these output levels: $\tau x_j^I + \frac{1-\tau}{n} x_j^U = x_j$. Next, we assume that sellers cannot distinguish an informed from an uninformed customer. Hence, we assume that sellers cannot price discriminate, implying that $p_j^I(x_1^I,\ldots, x_n^I, M)=p_j^U(x_j^U, M)$. Together these two conditions determine market demand.

Proposition 1. *Given the total output vector* $(x_1,\ldots, x_n)$*, the market equilibrium price for product j equals*

$$p_j(x1,\ldots,x_n) = 1-\beta x_j-\gamma \sum_{k\neq j} x_k$$

where

$$\gamma = \gamma(\sigma,\tau,n) = \frac{2n^2\sigma\tau}{[(1-\tau)(1-\sigma)+n\tau][n-(1-\tau)(1-\sigma)(n-1)]} \tag{2}$$

$$\beta = \beta(\sigma,\tau,n) = \gamma + \frac{2n(1-\sigma)}{(1-\tau)(1-\sigma)+n\tau} \tag{3}$$

Note that for $\tau=1$ we are back again in the usual case where $\beta=2$ and $\gamma=2\sigma$. That is, if the market is perfectly transparent we get the demand function which corresponds to the case where every consumer has utility function (1). Also note that for the case where $\tau<1$ and goods are perfect substitutes ($\sigma=1$), we get $\beta=\gamma=2$. So in that case β and γ do not depend on τ. The reason why β and γ for the case $\sigma<1$ depend on τ is that the firm faces two markets: one where decreasing marginal utility is strong (the uninformed market where consumers only buy the firm's own product) and one where it is weaker (because with $\sigma<1$ the informed consumers like variety and hence are willing to consume more).[5] The parameters τ and n determine the size of the uninformed market, which equals $\frac{1-\tau}{n}$. If $\sigma=1$, goods are perfect substitutes and marginal utility decreases at the same speed in both markets. Hence the relative sizes of these markets are irrelevant.

Finally, note that $\frac{\mathrm{d}p_j}{\mathrm{d}x} = -(\beta+(n-1)\gamma) < 0$. If all firms raise their output simultaneously by an amount dx, all prices will fall. Furthermore, it can be shown that $\frac{\partial(\beta+(n-1)\gamma)}{\partial\tau} < 0$, implying that the fall in p_j is bigger the smaller is τ. The intuition for this is that as τ decreases, more is sold on the uninformed market where marginal utility decreases faster than on the informed market. Hence, a given rise dx leads to a bigger fall in prices. From this we see immediately that, for given output levels, it is possible that a rise in transparency increases all prices p_j. If firms choose symmetric output levels, $x=x_1=\ldots=x_n$ then we have $p_j=1-(\beta+(n-1)\gamma)x$. For given x, a rise in transparency τ increases prices p_j. The intuition for this effect is that if consumers become better informed about the availability of goods which are imperfect substitutes then total demand will increase.[6] But if total supply is taken as given, the market equilibrium price must increase in order to restore the equality of demand and supply. This we call the *demand effect* of transparency, because supply is fixed in this analysis.

[5] The observation that marginal utility goes down faster on the uninformed market suggests that the firm would prefer to have informed consumers only. At first sight, this seems to contradict the idea that the firm is a monopolist on the uninformed market which makes this uninformed market more profitable than the informed one. The point is that we are taking output levels $x_1,\ldots, x_n$ fixed at this moment. The next section introduces the idea that output levels are determined in Nash equilibrium. This introduces the competition effect of transparency τ.

[6] The effect is even stronger when goods are complements ($\sigma<0$).

3. Cournot–Nash equilibrium

In this section, we analyze the equilibrium in case that firms compete in quantities. As the next proposition shows an increase in transparency will lead to increase in quantities. We focus on the case that firms have identical quadratic cost functions $c(x_i) = c_1 x_i + \frac{1}{2} c_2 x_i^2$.

Proposition 2. *The unique symmetric Cournot–Nash equilibrium (x^C,…, x^C) is characterized by* $\frac{1-c_1}{2\beta+(n-1)\gamma+c_2}$. *Furthermore, when $\sigma<1$ we have* $\frac{\mathrm{d}x^C}{\mathrm{d}\tau} > 0$.

Firms increase their output levels if more consumers become informed about available products and prices. This effect and its intuition are in line with the conventional wisdom regarding competition on transparent markets. The competition between firms becomes fiercer if the group of informed consumers becomes larger. This effect of transparency can be labeled the *competition effect* of transparency. The effect is not restricted to quadratic or convex cost functions. Moreover, it can be shown to hold also when firms compete in prices rather than quantities.

The competition effect does not necessarily imply, though, that prices will decrease as transparency increases. This is due to the demand effect that we have seen in the previous section.

Proposition 3. *With $\sigma<1$ it holds for the price $p^C = 1-(\beta+(n-1)\gamma)\, x^C$ in the symmetric Cournot–Nash equilibrium that*

$$\frac{\mathrm{d}p^C}{\mathrm{d}\tau} > 0 \ \textit{iff} \ \ c_2 > \overline{c}_2 \equiv \frac{2n^2\sigma}{(1-\sigma+(n-1+\sigma)\tau)^2}$$

If products are imperfect substitutes, total demand increases if more consumers become aware of more products. Hence, if the competition effect is "small" the demand effect may dominate. In particular, when supply is very inelastic, output will only marginally increase with transparency. Furthermore, it can be shown that $\frac{\mathrm{d}\overline{c}_2}{\mathrm{d}\sigma} > 0$, and $\frac{\mathrm{d}\overline{c}_2}{\mathrm{d}n} > 0$. As goods become closer substitutes and as the number of firms increases, the cost function needs to be more convex to get that a rise in τ raises prices. The intuition is that for higher σ consumers have a weaker taste for variety and hence the demand effect is smaller. If there are more firms, each firm is smaller and hence an increase in demand can be spread over more firms with relatively lower marginal costs.

Finally, we have a look at welfare effects. Since the equilibrium level of quantities x^C is increasing in τ, social welfare (defined as the sum of consumer and producer surplus) is also increasing in τ. This can be seen as follows. Social welfare is here defined as consumer surplus minus production costs as a function of output levels. The first derivative of welfare with respect to output of product *i* then equals the marginal utility of good *i* minus the marginal cost of good *i*. In this case, consumers' marginal utility of good *i* equals the price of good *i*. So the sign of the derivative of welfare with respect to the output level of good *i*, equals the sign of $p_i - c_1 - c_2 x_i^N$ which is positive. Furthermore, in those cases in which prices are decreasing in τ, profits are decreasing and consumer surplus is increasing in τ. However, it is not necessarily the case that consumers benefit from a rise in transparency. If supply is rather inelastic, consumers may loose, despite the fact that total output increases. The intuition for this result is as follows. A rise in τ has the two positive effects. First, it raises total output. Second, it increases the number of informed agents who have higher utility than the uninformed agents. The first positive effect can be reduced to zero by increasing c_2. The second positive effect is outweighed by the loss in utility of both informed and uninformed agents. These agents lose utility, because the increase in the number of informed agents raises demand for all goods and hence raises prices. Hence, if costs are very convex the competition effect of transparency is limited and consumer welfare can fall as τ rises.

4. Conclusion

The impact of transparency on prices and consumer surplus is more subtle than conventional wisdom seems to suggest. In our model an increase in transparency under some circumstances leads to an increase in prices and a decrease in consumer surplus. These effects are due to, what we have called, the demand effect of transparency. If goods are imperfect substitutes and consumers have a taste for variety, more widespread information about the availability of goods wets consumers appetite and shifts demand outward. This demand effect may counterbalance the downward pressure on prices due the competition effect of transparency. This is more likely to happen if supply is relatively inelastic. Goods for which this may be relevant include antiques, art, collectibles (such as, coins, stamps, toys, and sports cards), memorabilia, and land. For example, for someone collecting ancient coins one coin is not a perfect substitute for another coin. Compared to trading coins at fairs and local shops, we can expect that the possibility to trade over the Internet makes more people aware of a wide supply of coins. Our model suggests that this will lead to an increase in the demand for coins. Since the supply of ancient coins is more or less fixed, this will lead to an increase in prices. We believe that this is an interesting hypothesis that could, at least in principle, be tested empirically.

Acknowledgement

We acknowledge the helpful comments by a referee of this journal, by seminar participants at the University of Virginia and by participants of the Encore workshop on Market Transparency and by Tjalling de Vries in particular. We thank the Netherlands Organisation for Scientific Research (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW) for financial support (grant numbers 016.025.024, 453.03.606).

Appendix A. Proofs

Proof of Proposition 1. From $p_j^I(x_1^I,\ldots, x_n^I, M)=p_j^U(x_j^U, M)$ it follows that $x_j^I+\sigma\ \sum_{k\neq j}x_k^I=x_j^U$. Substitution into $\tau x_j^I + \frac{1-\tau}{n}x_j^U = x_j$ and rewriting yields

$$x_j^I = \frac{n}{n\tau + (1-\tau)(1-\sigma)}x_j - \frac{\sigma(1-\tau)}{n\tau + (1-\tau)(1-\sigma)}\sum_{k=1}^{n} x_k^I \tag{4}$$

Substituting into the expression for the price yields

$$\begin{aligned} p_j &= 1-2(1-\sigma)x_j^I-2\sigma\sum_{k=1}^{m} x_k^I = 1-\frac{2(1-\sigma)n}{n\tau + (1-\sigma)(1-\tau)}x_j-\left[2\sigma-\frac{2(1-\sigma)\sigma(1-\tau)}{n\tau + (1-\sigma)(1-\tau)}\right]\sum_{k=1}^{n} x_k^I \\ &= 1-\frac{2(1-\sigma)n}{n\tau + (1-\sigma)(1-\tau)}x_j-\left[\frac{2n\sigma\tau}{n\tau + (1-\sigma)(1-\tau)}\right]\sum_{k=1}^{n} x_k^I \end{aligned}$$

Summation of Eq. (4) over j and rewriting gives $\sum_{j=1}^{m} x_j^I = \frac{n}{n\tau + (1-\tau)(1-\sigma+\sigma n)} \sum_{j=1}^{n} x_j$. Inserting in the expression for p_j gives

$$p_j = 1 - \frac{2(1-\sigma)n}{n\tau + (1-\sigma)(1-\tau)} x_j - \frac{2n^2\sigma\tau}{[n\tau + (1-\sigma)(1-\tau)][n\tau + (1-\tau)(1-\sigma+\sigma n)]} \sum_{k=1}^{n} x_k$$

which corresponds to the expression in the Proposition. □

Proof of Proposition 2. The first order condition for x_j is: $1-2\beta x_j - \gamma \sum_{i \neq j} x_i - c_2 x_j - c_1 = 0$. Hence in the symmetric equilibrium we find that

$$x^{\mathrm{C}} = \frac{1-c_1}{2\beta + \gamma(n-1) + c_2}$$

To prove that $\frac{\mathrm{d}x^{\mathrm{C}}}{\mathrm{d}\tau} > 0$, we write the denominator of x^{C} as $\beta + (\beta + \gamma(n-1))$. From $\frac{\partial(\beta + (n-1)\gamma)}{\partial \tau} < 0$ and $\frac{\partial \beta}{\partial \tau} < 0$ it follows that $\frac{\mathrm{d}x^{\mathrm{C}}}{\mathrm{d}\tau} > 0$. □

Proof of Proposition 3. For the Cournot–Nash price we have

$$p^{\mathrm{C}} = 1 - (\beta + (n-1)\gamma)x^{\mathrm{C}} = 1 - (1-c_1)\frac{\beta + (n-1)\gamma}{\beta + \gamma(n-1) + \beta + c_2} = 1 - (1-c_1)\frac{1}{1 + \dfrac{\beta + c_2}{\beta + (n-1)\gamma}}$$

Hence

$$\frac{\mathrm{d}p^{\mathrm{C}}}{\mathrm{d}\tau} > 0 \Leftrightarrow \frac{\mathrm{d}\left[\dfrac{\beta + c_2}{\beta + (n-1)\gamma}\right]}{\mathrm{d}\tau} > 0$$

The last inequality can be written as

$$\frac{\dfrac{\mathrm{d}\beta}{\mathrm{d}\tau}(\beta + (n-1)\gamma) - (\beta + c_2)\dfrac{\mathrm{d}(\beta + (n-1)\gamma)}{\mathrm{d}\tau}}{(\beta + (n-1)\gamma)^2} > 0$$

or equivalently

$$c_2 > -\beta + (\beta + (n-1)\gamma)\frac{\left[\dfrac{\mathrm{d}\beta}{\mathrm{d}\tau}\right]}{\left[\dfrac{\mathrm{d}(\beta + (n-1)\gamma)}{\mathrm{d}\tau}\right]}$$

It is tedious but straightforward to verify that this can be written as

$$c_2 > \overline{c}_2 = \frac{2\sigma n^2}{(1-\sigma + (n-1+\sigma)\tau)^2}$$

□

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