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A Model with Endogenous Entry

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Yiquan Gu and Burkhard Hehenkamp[1]

The Inefficiency of Market Transparency – A Model with Endogenous Entry

Abstract

Including the entry decision in a Bertrand model with imperfectly informed consumers, we introduce a trade-off at the level of social welfare. On the one hand, market transparency is beneficial when the number of firms is exogenously given. On the other, a higher degree of market transparency implies lower profits and hence makes it less attractive to enter the market in the first place. It turns out that the second effect dominates: too much market transparency has a detrimental effect on consumer surplus and on social welfare.

JEL Classification: D43, L13, L15

Keywords: Market transparency; endogenous entry; homogenous products

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1 Introduction

Economists and others generally hold the view that consumer-sided market transparency benefits the functioning of markets and hence boosts welfare. Both theoretical and empirical evidence seem to underpin this. In this paper, we challenge this view, presenting a two-stage model where first firms independently decide whether to enter a market or not and then, knowing the number of entrants, pick prices. It turns out that too much market transparency generally harms competition and reduces social welfare once the entry decision is taken into account.

Including the entry decision in the model introduces a trade-off between static and dynamic efficiency. On the one hand, market transparency fosters competition and enhances social welfare when the number of firms is exogenously given. On the other, a higher degree of market transparency implies lower profits and hence makes it less attractive to enter the market in the first place. As our analysis reveals, the second effect dominates, provided that market transparency is sufficiently large.

To keep the model simple, we define (consumer-sided) market transparency as the share of informed consumers in the market. Informed consumers are fully informed and buy from the cheapest firm. When there are several cheapest firms, informed consumers distribute evenly. Uninformed consumers patronize a certain firm and do not compare prices. Still the amount actually purchased depends on the price charged at their favorite firm.

There are three strands of literature to which we connect. The literature on *market transparency* is comprehensive. We perceive market transparency as a broader term encompassing different aspects of market information.

Papers with *common and captive markets* have firms facing a common market, in which they compete, and a captive market, where they can monopolize on their consumers (Shilony, 1977; Varian, 1980; Rosenthal, 1980). In our model informed consumers make up the common, uninformed consumers the captive market. Given that firms cannot price discriminate between these markets, equilibrium pricing is in mixed strategies, involving prices above marginal cost.

Sluggish consumers (or demand inertia, as Selten calls it more technically) allow firms to exercise market power (Hehenkamp, 2002; Selten, 1965). Even if consumers have full information on prices, but do not all respond to it, firms raise prices above marginal cost. In the case of extremely sluggish consumers, monopoly pricing results. The share of responsive consumers in this context corresponds to the share of informed consumers in our model.

Finally, the literature on *consumer search* has shown that firms gain market power if consumers have to search for prices and if this search is costly (see e.g. Stahl, 1989; Robert & Stahl, 1993). Stahl's model of shoppers and non-shoppers can be embedded into our model if search cost is high. In Stahl (1989), shoppers have zero search cost and are perfectly informed about prices; non-shoppers search rationally, i.e. they compare the expected benefit of continued search with the corresponding search cost. Stahl's endogenously determined fraction of shoppers and informed non-shoppers then equates to our share of informed consumers.

In all the above papers, an increase in market transparency reduces the firms' ability to raise prices above marginal cost and hence is beneficial for welfare.

The second strand of literature deals with models of *endogenous entry.* When *homogeneous products* are considered, an increase in the number of potential entrants surprisingly reduces welfare (Lang & Rosenthal, 1991; Elberfeld & Wolfstetter, 1999). The two papers differ in the timing of entry and pricing. In Lang & Rosenthal (1991) both decisions are made simultaneously, in Elberfeld & Wolfstetter (1999) firms first decide upon entry and then, knowing the number of entrants, they choose prices. In both papers entry is in mixed strategies and the market is fully transparent. One might debate whether pure or mixed strategies are more reasonable at the entry stage. Dixit & Shapiro (1986) and Schultz (2009) number pros and cons of pure and *mixed entry strategies*, which we do not want to repeat here. However, both types of equilibria seem relevant to the analysis of market entry.

Finally, there is a third strand of literature, which connects market transparency with entry decisions (Gu & Wenzel, 2009a,b; Schultz, 2009). All these models deal with *differentiated products.* The effect of market transparency on welfare is unambiguous: more transparency entails higher social welfare, even when entry decisions are included in the modeling framework.

We proceed as follows. Section 2 presents the model, Section 3 the equilibrium analysis, and Section 4 the welfare analysis. Section 5 concludes.

2 The model

We examine a homogeneous product market with endogenous entry. A share $\phi \in [0, 1]$ of all consumers is informed, i.e., they know all prices quoted in the market. The remaining consumers are uninformed about prices. In what follows, we refer to ϕ as (the degree of) *market transparency.*

The market game

The market game consists of two stages. At stage 1, $N \geq 2$ firms decide whether to enter the product market or not. Entry costs $f > 0$. Let $\mathcal{N} := \{1, \ldots, N\}$ denote the corrresponding set of potential entrants. At stage 2, entry costs are sunk. Knowing how many firms entered at stage 1, the entrants compete in prices for the informed consumers. Let $\mathcal{K} = \{1, \ldots, K\}$ denote the corresponding set of actual entrants (after appropriate relabeling).

The N symmetric firms have access to an identical constant returns to scale technology. Marginal cost crosses market demand. Without loss of generality, we normalize the marginal cost of production to zero. Each entrant $i \in \mathcal{K}$ sets a non-negative price $p_i \in \mathcal{P} = [0, \infty)$.

Market demand is given by a measurable and integrable function $D(p)$, mapping non-negative prices into non-negative demand. Market revenue $R(p) := pD(p)$ attains a unique global maximum at some price p^m and is strictly increasing on $[0, p^m]$. Furthermore, market demand is bounded, non-increasing, and continuous on $[0, p^m]$.

Entry cost f of stage 1 satisfies two conditions: first, not all firms can profitably contest the market simultaneously, even if firms colluded perfectly, i.e. $f > R^m/N$; second, one firm alone would find it profitable to supply the market, i.e. $f < R^m$; in sum, we assume $f \in (R^m/N, R^m)$.

Central to our welfare analysis will be consumer surplus,

$$CS(p) := \int_p^\infty D(\widetilde{p})\, d\widetilde{p}.$$

Notice that $CS(p)$ is well defined and finite for any price $p \in \mathcal{P}$, since $D(p)$ is assumed measurable and integrable. Moreover, $CS(p)$ is continuously differentiable on $[0, p^m]$ by continuity of $D(p)$ on $[0, p^m]$.

Bertrand preferences

We further assume that consumers exhibit *Bertrand preferences* (Hehenkamp, 2002):

- Informed consumers buy from the cheapest firm. Given there are several, they distribute evenly.
- Uninformed consumers patronize their 'favorite' firm. Consumers' favorite firms are distributed uniformly as well.

Like in the standard Bertrand model, preferences for low prices and favorite firms are lexicographic. From the perspective of firms, uninformed consumers are patrons: lower prices by other firms will not make them switch firms.

According to the assumption of Bertrand preferences, revenue of any entrant $i \in \mathcal{K}$ reads,

$$R_i(p_1, \ldots p_K) = \begin{cases} \frac{1-\phi}{K} R(p_i) & \text{if } p_i > \min\{p_1, \ldots p_K\} \\ \left(\frac{1-\phi}{K} + \frac{\phi}{\#\mathcal{I}(p)}\right) R(p_i) & \text{if } p_i = \min\{p_1, \ldots p_K\} \end{cases},$$

where $\#\mathcal{I}(p)$ is the number of entrants who tie at the lowest price, given a profile of prices, $p = (p_1, \ldots p_K)$.

3 Equilibrium analysis

We solve the game by backward induction, first analyzing the pricing games that arise at stage 2.

Stage 2: Pricing behavior

Three cases can occur. First, no firm has entered: the market does not come into existence. Second, one firm has entered: this firm faces a monopoly position. Third, two or more firms have entered: we have *hybrid Bertrand competition*, that is, firms compete for both informed and uninformed consumers.

When no firm enters, i.e. $K = 0$, all firms earn zero profit and consumer surplus is zero; no efficiency gain is realized,

$$\pi_i = 0, \quad CS = 0.$$

When $K = 1$, the monopolist will charge the monopoly price p^m, realizing a revenue of $R^m := R(p^m)$ and earning positive profit; consumer surplus is 'low':

$$\pi^m := R^m - f > 0, \quad CS^m := CS(p^m).$$

The market outcome in these first two cases does not depend on market transparency ϕ.

The oligopoly case

In the oligopoly case ($K \geq 2$), we distinguish three (sub)cases, which differ in the degree of market transparency.

No transparency ($\phi = 0$). All consumers are uninformed, effectively there is no competition among the entrants. Each of them gets a share of $1/K$ consumers and sets p^m to obtain a revenue of R^m/K; profit can be both positive or negative, depending on K; consumer surplus corresponds to that of the monopoly case,

$$\pi_i = \frac{R^m}{K} - f \lesseqgtr 0, \quad CS^K_{\phi=0} = CS\left(p^m\right).$$

Full transparency ($\phi = 1$). All consumers are perfectly informed, the pricing game reduces to a standard Bertrand oligopoly. In equilibrium, at least two entrants price at marginal cost (of zero), all consumers buy at marginal cost, all entrants earn zero revenue, and consumer surplus is 'maximal',

$$\pi_i = -f < 0, \quad CS^K_{\phi=1} = CS\left(0\right).$$

Intermediate transparency ($\phi \in (0,1)$). For intermediate values of market transparency, the pricing equilibrium changes qualitatively:

Proposition 1 *If $K \geq 2$ and $\phi \in (0,1)$, then there exists no equilibrium in pure strategies.*

Proof. Our proof consists of two parts. First, we show that there is no symmetric equilibrium in pure strategies. Subsequently, we establish that no asymmetric equilibrium in pure strategies exists either.

As to the first claim, notice that no symmetric price profile $(p, \ldots, p)$ with $p > p^m$ can represent an equilibrium. For, in this case the monopoly price p^m yields strictly higher payoff than does p (this is independent of ϕ). If all firms charge an identical price from $(0, p^m]$, slightly undercutting this price would produce a jump in a firm's share of consumers from $1/K$ to $(1-\phi)/K + \phi$ and hence be profitable. Finally, a price of 0 is strictly dominated by p^m when $\phi < 1$, since by charging p^m a firm can obtain a revenue of $(1-\phi) R^m/K > 0$.

To prove the second claim, suppose there were an asymmetric price equilibrium $(p_1, \ldots, p_K)$, i.e. $\min_i p_i < \max_j p_j$. By the above dominance argument we have $\min p_i > 0$. Moreover, at most one firm will have the lowest price. This follows from the discontinuity argument used in the symmetric case. All other firms must then charge p^m, since, conditional on not charging the lowest price, p^m is the best choice. When all other firms charge p^m, however, no price strictly below p^m is optimal. This is because there is no highest price that is strictly lower than p^m. ■

Yet, there exists a unique symmetric equilibrium in mixed strategies. We will first derive the equilibrium strategy and subsequently explore its properties.

The symmetric mixed pricing equilibrium

In a symmetric mixed pricing equilibrium all firms adopt a common cumulative distribution function (cdf). Denote this by $H(p) = \Pr\{P \leq p\}$. Economically, $H(p)$ represents a firm's probability of setting a price P less than p. It is sometimes convenient to work with the complementary probability $\overline{H}(p) := 1 - H(p) = \Pr\{P > p\}$.

Proposition 2 *$H(p)$ has no atoms.*

Proof. We confine ourselves with providing the underlying intuition. For a more detailed elaboration of the argument, see Proposition 3 in Varian (1980).

Suppose $H(p)$ would have an atom at some price $\widehat{p}$. Then price $\widehat{p}$ will be played with positive probability and hence two (or more) firms will tie at $\widehat{p}$ with positive probability $\widehat{p}$. If $\widehat{p} > 0$ then a player would gain by shifting the probability mass of the atom towards a slightly lower price $\widehat{p} - \xi$, for $\xi > 0$ sufficiently small. If $\widehat{p} = 0$, then a player would gain by shifting the probability mass of the atom to the monopoly price p^m. ■

We have already argued that no firm will ever charge a price $p > p^m$. Therefore, the largest price ever set is the monopoly price p^m. Charging the monopoly price, an entrant will loose all informed consumers, but it monopolizes on its patrons. In this case he clears $(1-\phi) R^m/K$. This is the right-hand side of equation (1).

Moreover, a symmetric mixed strategy $H(p)$ must leave an entrant indifferent between all prices that are actually used. Correspondingly, the left-hand side of equation (1) represents the expected revenue at any price p,

$$\left[\frac{1-\phi}{K} + \left(\overline{H}(p)\right)^{K-1}\phi\right] R(p) = \frac{1-\phi}{K} R^m. \tag{1}$$

The first term in the brackets represents an entrant's share of uninformed consumers. The second term includes the share of informed consumers, which only show up when the entrant charges the minimum price. This happens with probability $\left(\overline{H}(p)\right)^{K-1}$. We can now solve equation (1) for $\overline{H}(p)$, which yields

$$\overline{H}(p) = \left(\frac{1-\phi}{\phi}\frac{R^m - R(p)}{KR(p)}\right)^{\frac{1}{K-1}}. \tag{2}$$

This equality holds for all prices in the support.

The infimum of all prices in the support, $\underline{p}$, corresponds to that price $p \in [0, p^m]$ that satisfies

$$R(p)\left[\frac{1-\phi}{K} + \phi\right] = \frac{1-\phi}{K} R^m$$

$$\Longleftrightarrow \qquad R(p) \quad = \quad \frac{1-\phi}{(K-1)\phi+1} R^m \tag{3}$$

Observe that $\underline{p}$ is uniquely defined, since $R(p)$ is assumed strictly increasing on $[0, p^m]$. Charging $\underline{p}$, a firm will have the minimum price with probability one (recall Prop. 2) and hence attract all informed consumers.

Proposition 3 *When $K \geq 2$ firms have entered the market and market transparency is intermediate, $\phi \in (0,1)$, there exists a unique symmetric mixed strategy pricing equilibrium. The corresponding equilibrium strategy is characterized by the following cumulative distribution function:*

$$H(p) = \begin{cases} 1 - \left(\frac{1-\phi}{\phi} \frac{R^m - R(p)}{K R(p)} \right)^{\frac{1}{K-1}} & \text{for} \quad \underline{p} \leq p \leq p^m \\ 0 & \text{for} \quad p < \underline{p} \\ 1 & \text{for} \quad p > p^m. \end{cases}$$

Proof. First, because $R(p)$ is continuous, the intermediate value theorem implies that $\underline{p}$ is well defined and that $\underline{p} < p^m$.

Second, the function $H(p)$ indeed represents a cumulative probability distribution: As stated in Proposition 2, $H(p) = 1 - \overline{H}(p)$ is continuous on $[\underline{p}, p^m]$. Moreover, we have $H(\underline{p}) = 0$ and $H(p^m) = 1$ for all $\phi \in (0,1)$ and $H(p)$ is non-decreasing in p.

Finally, prices $p < \underline{p}$ and $p > p^m$ imply expected profit strictly lower than $(1-\phi) R^m / K$. Hence $H(p)$ maximizes an entrants expected profit given that all other firms use $H(p)$ as well. ■

The equilibrium strategy in the case of intermediate transparency coincides with that of Rosenthal (1980), if we set $(1-\phi) D(p) / K$ as market demand of the captive market and $\phi D(p)$ as market demand in the common market. Observe, however, that changing the degree of market transparency affects the relative size of the captive and the common market.

The following proposition collects expressions for expected profit and expected consumer surplus, respectively.

Proposition 4 *Let $K \geq 2$ and $\phi \in (0,1)$. Then we find:*
(a) The expected revenue of each entrant corresponds to the expected payoff of the monopoly price. Expected profit thus reads

$$\pi_i = \frac{1-\phi}{K} R^m - f.$$

(b) The expected consumer surplus is given by

$$CS_\phi^K = \phi \int_{\underline{p}}^{p^m} CS(p)\, dH_{(1)}(p) + (1-\phi) \int_{\underline{p}}^{p^m} CS(p)\, dH(p),$$

where $H_{(1)}(p)$ denotes the cdf of the minimum price of all firms.

According to part (a), each entrant skims the complete informational rent from its patrons. Part (b) contains two terms. The first represents the consumer surplus of the informed consumers. Informed consumers only pay the minimum price, which is the first order statistic of K prices independently chosen from distribution H. The second term gives the consumer surplus of the uninformed consumers.

Properties of the pricing equilibrium

We have seen that both a fully transparent market ($\phi = 1$) and a completely non-transparent market ($\phi = 0$) give rise to a pure strategy equilibrium (of marginal cost and monopoly pricing, resp.) How does our model behave in the case of intermediate transparency when we take the limits of $\phi \rightarrow 1^-$ and $\phi \rightarrow 0^+$?

Proposition 5 *Let $K \geq 2$ and $\phi \in (0, 1)$.*
(a) As $\phi \rightarrow 0^+$, the Nash equilibrium strategy $H(p)$ converges (in probability) to a degenerate probability distribution with unit probability mass on the monopoly price.
(b) As $\phi \rightarrow 1^-$, the Nash equilibrium strategy $H(p)$ converges (in probability) to a degenerate probability distribution with unit probability mass on marginal cost.

Proof. Weak convergence can be shown easily, using the equilibrium strategy derived in Proposition 3. Convergence in probability is implied because the limit distribution has all probability on a single price (i.e. the corresponding limit random variable is constant). ■

According to Proposition 5, our model behaves smoothly at the boundaries of no and full transparency, respectively.

We end the analysis of stage 2 with the comparative static effect of transparency on the symmetric mixed pricing equilibrium. Since the equilibrium strategy represents a distribution function, monotonicity of a firm's price and the minimum price is phrased in terms of the usual stochastic order (which is based on what is commonly called 'first order stochastic dominance').

Proposition 6 *Let $K \geq 2$ and $\phi \in (0, 1)$. The more transparent the market (the higher ϕ), the lower a firm's price, the lower the minimum price of all entrants (both in stochastic terms), and the higher expected consumer surplus.*

Proof. To see (a), observe that $\overline{H}(p)$, considered as function of ϕ, decreases with ϕ. Hence, a price strategy $H(p)$ corresponding to low market transparency ϕ' stochastically dominates another that corresponds to some larger degree of market transparency ϕ'', for any $\phi' < \phi''$. The distribution of the first order stochastic, $H_{(1)}(p)$, (which is the minimum price here) inherits all stochastic monotonicity properties from its parent distribution, $H(p)$ (see Theorem 4.4.1 in David & Nagaraja, 2003). Finally, consumer surplus is a bounded, continuous function, and strictly decreasing function of p on the interval $[0, p^m]$. The claim hence follows from Theorem 1.A.3 in Shaked & Shanthikumar, (2007). ■

According to Proposition 6, market transparency has the intuitive effect of intensifying competition and increasing consumer surplus, given the number of entrants is fixed.

Stage 1: Entry decisions

Having analyzed the equilibrium behavior of stage 1, we now proceed to investigate the entry decision of a single firm. Again, we confine our analysis to symmetric equilibria.

First of all, notice that there is no symmetric equilibrium in pure strategies. Recall that $f \in (R^m/N, R^m)$. If all firms enter, they incur losses because of $f > R^m/K$. Hence, no entry would be strictly better (given the other firms stick with entry). If no firm enters, entry is profitable because of $f < R^m$ (given the other firms remain outside the market)

We now show that there is a symmetric entry equilibrium in mixed strategies. Let ε denote the probability of entry in this equilibrium. Each firm has to be indifferent between 'entry' and 'no entry'. Since 'no entry' entails zero profit, 'entry' does so too:

$$(1-\varepsilon)^{N-1} R^m + \sum_{i=1}^{N-1} \binom{N-1}{i} \varepsilon^i (1-\varepsilon)^{N-i-1} \frac{(1-\phi) R^m}{i+1} = f. \tag{4}$$

The left-hand side of (4) contains the expected revenue of entry, which has to equal the entry cost f. The left-hand side collects the revenue terms associated with the different number of other firms entering the market. If no other firm enters, the entrant becomes monopolist, earning monopoly revenue R^m. This happens with probability $(1-\varepsilon)^{N-1}$. If i other firms enter, then there will be hybrid Bertrand competition among $i+1$ firms. Accordingly, the entrant earns $(1-\phi) R^m/(i+1)$ (see Prop. 4). This happens with probability $\binom{N-1}{i}\varepsilon^i (1-\varepsilon)^{N-i-1}$.

Dividing (4) by R^m, one can simplify (4) to obtain

$$(1-\varepsilon)^{N-1} + (1-\phi)\,\frac{1-(1-\varepsilon)^N - N\varepsilon\,(1-\varepsilon)^{N-1}}{N\varepsilon} = \frac{f}{R^m}. \qquad (5)$$

It can be shown that the left-hand side of (5) is strictly decreasing in ε. Moreover, the left-hand side assumes $(1-\phi)/N \leq 1/N < f/R^m$ for $\varepsilon = 1$ and goes to $1 > f/R^m$ as $\varepsilon \to 0$. By the intermediate value theorem, there hence exists a unique ε satisfying (5), for any $\phi \in [0,1]$. We have established:

Proposition 7 *For any degree of market transparency $\phi \in [0,1]$, there exists a unique symmetric equilibrium in mixed strategies at the entry stage. The corresponding probability of entry is implicitly given by (4) or (5).*

We finish the equilibrium analysis with results on the comparative static properties of this equilibrium:

Proposition 8 *Entry is the less likely,*
(a) the more transparent the market (the higher ϕ) and
(b) the less profitable the market (the higher f/R^m).

Proof. The claims hold because the left-hand side of (5) is decreasing in ε and ϕ. ∎

4 Social welfare

In this section we present our main finding: Too much market transparency is detrimental to social welfare.

To begin with, observe that *ex ante* expected producer surplus is zero. Therefore consumer surplus and social welfare coincide. Social welfare W is hence given by

$$W = N\varepsilon\,(1-\varepsilon)^{N-1}\,CS^m + \sum_{K=2}^{N} \binom{N}{K} \varepsilon^K\,(1-\varepsilon)^{N-K}\,CS_\phi^K. \qquad (6)$$

To establish our main finding, we show that social welfare decreases in the limit as the market becomes fully transparent ($\phi \to 1$). Taking this limit, firms' prices converge to marginal cost (recall Proposition 5). It would be quite natural to assume that the resulting increase in demand is bounded as the market price approaches marginal cost. However, the following more general assumption turns out to be sufficient for our purpose.

Assumption D *Demand $D(p)$ is differentiable on $(0, p^m]$ and satisfies* $\lim_{p\to 0} pD'(p) = 0$.[1]

We then have:

Theorem *Let Assumption D be met, suppose that there are N potential entrants, $N < \infty$, and let entry cost satisfy $f \in (R^m/N, R^m)$. Further assume that either of the following two conditions holds:*

$$\text{(a)} \quad CS(0) - CS^m - R^m > 0 \quad \text{or} \quad \text{(b)} \quad CS^m > 0.$$

Then social welfare decreases with market transparency ϕ for ϕ sufficiently large.

Proof. See the appendix. ■

The theorem above identifies two mild conditions as sufficient for the negative impact of too much transparency. Condition (a) posits a strictly positive deadweight loss (associated with the case of monopoly). Condition (b) postulates a strictly positive consumer surplus at the monopoly price. Notice that conditions (a) and (b) always hold weakly.

Both conditions could easily be replaced by conditions on the (primitive) demand function. For instance, condition (b) would be implied if $D(p)$ were assumed continuous at p^m from both sides (or, less generally, on the interval $[0, \infty)$). Similarly, condition (a) would follow if $D(p)$ were assumed strictly decreasing at some price $p \in (0, p^m)$ (or, less generally, on the whole interval $(0, p^m)$).

Both conditions are weak in that the remaining class of demand functions, not covered by the theorem, is small. These are the constant demand functions of the type

$$D(p) = \begin{cases} d & \text{for } p \in [0, \widehat{p}] \\ 0 & \text{if } p > \widehat{p} \end{cases},$$

where $\widehat{p}, d > 0$. As can be shown easily, the theorem does not extend to this class of demand functions, since the marginal effect of transparency on welfare is always positive (and only vanishes in the limit as $\phi \to 1$).[2]

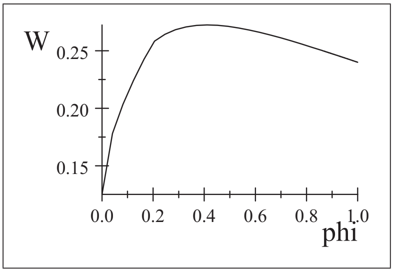
[1] That is, we allow for $\lim_{p\to 0} D'(p) = -\infty$. In that case, Assumption D requires that convergence is at a rate lower than that of $p \to 0$.

[2] For unit demand functions (where $d = 1$), Schultz (2009) makes a similar observation. Investigating a model of product differentiation, he addresses the case of 'the almost homogeneous market' by taking the limit of transportation cost to zero (see his sections 4 and 5). Social welfare is then maximal in this limit.

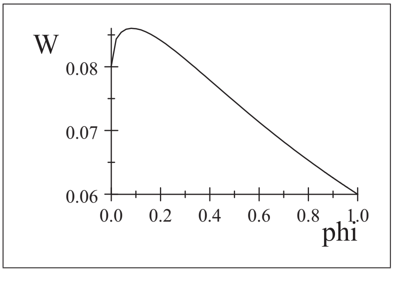
The optimal level of transparency

We end this section with illustrating that the optimal level of market transparency can be quite low. To this end, we consider the example of linear demand, $D(p) = 1 - p$.

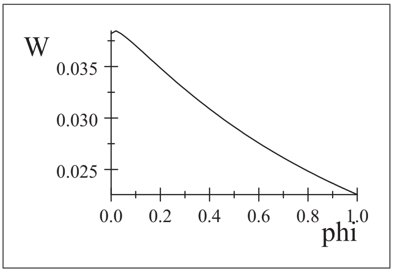
Example *The following three figures each plot social welfare as a function of market transparency ϕ for the case of $N = 2$ potential entrants. The figures differ in the size of entry cost f. Observe that entry cost need to satisfy $f < R^m = 1/4$ (otherwise no firm enters) and $(1-\phi)/8 < f$ (otherwise each firm enters with probability one). For a given level of entry cost, the latter condition provides a lower bound on market transparency (see the first figure).*
(Low entry cost) Let $f = 1/10$. This implies $\varepsilon = \frac{6}{5(\phi+1)}$ and $\phi \geq 1/5$.



(Intermediate entry cost) Let $f = 1/5$. This implies $\varepsilon = \frac{2}{5(\phi+1)}$, which satisfies $\varepsilon \in (0,1)$ for all $\phi \in [0,1]$.



(High entry cost) Let $f = 11/48$. This implies $\varepsilon = \frac{1}{6(\phi+1)}$, which satisfies $\varepsilon \in (0,1)$ for all $\phi \in [0,1]$, as well.



In all three cases the welfare-optimal level of market transparency is below 0.5*. Moreover, the three plots indicate that the optimal level of transparency decreases with the size of entry cost.*

5 Conclusion

We have provided a framework in which *too much market transparency harms competition and reduces social welfare* under fairly general conditions. Society faces a trade-off: On the one hand, more transparency intensifies competition, lowers prices and enhances welfare in each oligopoly subgame of stage 2 (in terms of the usual stochastic order). On the other hand, this reduces the profitability of entry, which causes firms to reduce their probability of entry. Hence, market breakdown becomes more and oligopoly less likely. As our main result shows, the second effect dominates when the market becomes sufficiently transparent.

To establish our welfare result we need either one of two weak conditions on the demand function: *At the monopoly price* the demand function either has to exhibit (1) *a strictly positive consumer surplus* or it has to display (2) *a strictly positive deadweight loss* (or both). The only class of demand functions not covered by these conditions are constant demand functions (of which unit demand functions represent a special case).

Our theorem identifies this class as special in two ways. Recall first that social welfare coincides with consumer surplus, because *ex ante* the producer surplus will be eaten up by the entry costs. Then the violation of (1), i.e. zero consumer surplus in the monopoly case, takes away one comparative advantage of market coverage over market breakdown. In particular, monopoly is put on the same level with market breakdown. The violation of condition (2), i.e. zero deadweight loss at the monopoly price, takes away the welfare gain from competition (relative to monopoly). Both effects weaken the negative welfare effect of market transparency caused via the reduction in entry probability. This is why, *(only) for constant demand functions*, the welfare effect of transparency is unambigously positive.

We have also imposed two conditions that guarantee an equilibrium with entry in mixed actions. These conditions relate market profitability, entry cost, and the number of potential entrants to each other. First, the market needs to be profitable to at least a single entering firm. Second, there has to be a sufficiently large pool of potential entrants such that firms incur losses in case all potential entrants should happen to enter the market. The role of these assumptions is merely to keep the model as simple as possible. Resorting to Harsanyi's purification theorem (Harsanyi, 1973), we could as well have introduced uncertainty about entry cost into the model in order to obtain equilibrium entry in pure actions.

Finally, we relate our findings to the product differentiation literature on market transparency and endogenous entry. This literature has found a unique positive welfare effect of market transparency. Comparing with Schultz (2009), the notion of entry does not seem to play a crucial role, since we and Schultz (2009) apply the same notion. Most of the product differentiation literature, however, focuses on the case of price-inelastic unit demand. As we have just learned from our welfare theorem, this assumes away the crucial channels of how market transparency can negatively affect social welfare. The restriction to unit demand functions might thus be not as innocent as is usually considered.

Appendix: Proof of the theorem

After some preliminary results, we first investigate the marginal impact of ϕ on the entry probability ε in the limit as $\phi \to 1$. Subsequently, we examine the marginal impact of ϕ on the consumer surplus CS_ϕ^K of any K-firm oligopoly in the limit as $\phi \to 1$. Finally, we combine these two results to show that the total marginal effect of ϕ on *ex ante* expected welfare is negative in the limit as $\phi \to 1$.

Preliminaries

As to the K-firm oligopoly case with intermediate transparency $\phi \in (0,1)$, we derive the following preliminary results from the firms' equilibrium pricing strategy:

$$\begin{aligned} H^K(p) &= 1 - \left(\frac{1-\phi}{K\phi} \frac{R^m - R(p)}{R(p)} \right)^{\frac{1}{K-1}} \\ H^K_{(1)}(p) &= 1 - \left(1 - H^K(p)\right)^K \end{aligned}$$

$$
\begin{aligned}
h^K(p) &= \frac{1-\phi}{K(K-1)\phi}\left(\frac{1-\phi}{K\phi}\frac{R^m-R(p)}{R(p)}\right)^{\frac{2-K}{K-1}}\frac{R^m R'(p)}{R^2(p)} \\
h_{(1)}^K(p) &= K\left(1-H^K(p)\right)^{K-1}h^K(p) \\
\overline{h}^K(p) &= \phi h_{(1)}^K(p)+(1-\phi)\,h^K(p) \\
&= \frac{(1-\phi)^2}{K(K-1)\phi}\frac{(R^m)^2 R'(p)}{R^3(p)}\left(\frac{1-\phi}{K\phi}\frac{R^m-R(p)}{R(p)}\right)^{\frac{2-K}{K-1}} && (7) \\
&= \frac{(1-\phi)R^m}{R(p)}h^K(p) && (8) \\
\frac{d\overline{h}^K(p)}{d\phi} &= -\frac{(K-1)\phi+1}{(K-1)\phi(1-\phi)}\overline{h}^K(p) && (9) \\
R\left(\underline{p}^K\right) &= \frac{1-\phi}{(K-1)\phi+1}R^m \\
\overline{h}^K\left(\underline{p}^K\right) &= \frac{[(K-1)\phi+1]^3}{K(K-1)\phi(1-\phi)}\frac{R'\left(\underline{p}^K\right)}{R^m} \\
\frac{d\underline{p}^K}{d\phi} &= \frac{-K}{[(K-1)\phi+1]^2}\frac{R^m}{R'\left(\underline{p}^K\right)} && (10)
\end{aligned}
$$

Probability of entry

The equilibrium probability of entry ε is implicitly given by

$$
(1-\varepsilon)^{N-1}+(1-\phi)\frac{1-(1-\varepsilon)^N-N\varepsilon(1-\varepsilon)^{N-1}}{N\varepsilon}=\frac{f}{R^m}.
$$

Using the implicit function theorem, we determine the marginal impact of transparency on the entry probability

$$
\frac{d\varepsilon}{d\phi}=\frac{-\varepsilon\left(1-(1-\varepsilon)^N-N\varepsilon(1-\varepsilon)^{N-1}\right)}{(1-\phi)\left[1-(1-\varepsilon)^N-N\varepsilon(1-\varepsilon)^{N-1}\right]+\phi N(N-1)\varepsilon^2(1-\varepsilon)^{N-2}}.
$$

This expression is clearly negative. Moreover, in the limit as $\phi\to 1$, we have

$$
\lim_{\phi\to 1}\frac{d\varepsilon}{d\phi}=-\frac{1-(1-\widehat{\varepsilon})^N-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{N(N-1)\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-2}}, \tag{11}
$$

where $\widehat{\varepsilon}$ denotes the entry probability when $\phi\to 1$, i.e.

$$
\widehat{\varepsilon}=1-(f/R^m)^{1/(N-1)}. \tag{12}
$$

Notice that $\widehat{\varepsilon}\in(0,1)$ because $f\in(R^m/N,R^m)$.

Consumer surplus of a K-firm oligopoly

When $K \geq 2$ firms have entered the market, consumer surplus is (after suppressing the index K)

$$CS_{\phi}^{K} = \int_{\underline{p}(\phi)}^{p^m} CS(p)\,\overline{h}(p)\,dp.$$

The marginal impact of ϕ on CS_{ϕ}^{K} is given by

$$\begin{aligned}
\frac{dCS_{\phi}^{K}}{d\phi} &= -CS\left(\underline{p}(\phi)\right)\overline{h}\left(\underline{p}(\phi)\right)\frac{d\underline{p}}{d\phi} + \int_{\underline{p}(\phi)}^{p^m} CS(p)\frac{d\overline{h}(p)}{d\phi}dp \\
&= CS\left(\underline{p}(\phi)\right)\frac{(K-1)\phi+1}{(K-1)\phi(1-\phi)} - \frac{(K-1)\phi+1}{(K-1)\phi(1-\phi)}CS_{\phi}^{K} \\
&= \frac{(K-1)\phi+1}{(K-1)\phi}\frac{CS\left(\underline{p}(\phi)\right)-CS_{\phi}^{K}}{(1-\phi)}, \qquad (13)
\end{aligned}$$

where the second equality follows from equations (7), (9), and (10).

We decompose the second fracture into two terms,

$$\frac{CS\left(\underline{p}(\phi)\right)-CS_{\phi}^{K}}{(1-\phi)} = \frac{CS\left(\underline{p}(\phi)\right)-CS(0)}{(1-\phi)} + \frac{CS(0)-CS_{\phi}^{K}}{(1-\phi)}. \qquad (14)$$

Taking the limit $\phi \to 1$, the first term reduces to

$$\begin{aligned}
&\lim_{\phi\to1}\frac{CS\left(\underline{p}(\phi)\right)-CS(0)}{(1-\phi)} \\
&= \lim_{\phi\to1}\left(D\left(\underline{p}(\phi)\right)\frac{d\underline{p}(\phi)}{d\phi}\right) \\
&= \lim_{\phi\to1}\left(D\left(\underline{p}(\phi)\right)\frac{-K}{[(K-1)\phi+1]^2}\frac{R^m}{R'\left(\underline{p}^K\right)}\right) \\
&= \left(\lim_{\phi\to1}\frac{-KR^m}{[(K-1)\phi+1]^2}\right)\left(\lim_{\phi\to1}\frac{D\left(\underline{p}(\phi)\right)}{D\left(\underline{p}(\phi)\right)+\underline{p}(\phi)D'\left(\underline{p}(\phi)\right)}\right) \\
&= -\frac{R^m}{K}, \qquad (15)
\end{aligned}$$

where the first equality follows from applying l'Hôpital's rule and the second from equation (10). The last equation holds because the second limit is one by Assumption (D).

To evaluate the second term, we divide it by R^m,

$$\begin{aligned}\frac{CS(0)-CS_\phi^K}{(1-\phi)R^m} &= \frac{1}{(1-\phi)R^m}\int_{\underline{p}(\phi)}^{p^m}\left(\int_0^p D(\widetilde{p})\,d\widetilde{p}\right)\overline{h}(p)\,dp \\ &= \int_{\underline{p}(\phi)}^{p^m}\frac{\left(\int_0^p D(\widetilde{p})\,d\widetilde{p}\right)}{R(p)}h(p)\,dp \\ &= \int_{\underline{p}(\phi)}^{p^m}\Psi(p)\,h(p)\,dp, \qquad (16)\end{aligned}$$

where the second equality follows from equation (8) and the third from setting $\Psi(p) := \left(\int_0^p D(\widetilde{p})\,d\widetilde{p}\right)/R(p)$ for any price $p \in (0, p^m]$. By Proposition 5, as $\phi \to 1$, the Nash equilibrium strategy converges (in probability) to the degenerate mixed strategy assigning probability one to marginal cost. Moreover, notice that $\Psi(p)$ is continuous on $p \in (0, p^m]$ and that, by Assumption (D),

$$\lim_{p\to 0}\Psi(p) = \lim_{p\to 0}\frac{D(p)}{D(p)+pD'(p)} = 1.$$

Since the last expression in (16) represents the expected value of $\Psi(p)$ under the symmetric Nash equilibrium strategy $H(p)$, we thus obtain

$$\lim_{\phi\to 1}\frac{CS(0)-CS_\phi^K}{(1-\phi)R^m} = \lim_{\phi\to 1}\int_{\underline{p}(\phi)}^{p^m}\Psi(p)\,h(p)\,dp = 1. \qquad (17)$$

Combining (15) and (17), we obtain the limit of (14) as $\phi \to 1$,

$$\begin{aligned}\lim_{\phi\to 1}\frac{CS\left(\underline{p}(\phi)\right)-CS_\phi^K}{(1-\phi)} &= \lim_{\phi\to 1}\frac{CS\left(\underline{p}(\phi)\right)-CS(0)}{(1-\phi)} + \lim_{\phi\to 1}\frac{CS(0)-CS_\phi^K}{(1-\phi)} \\ &= \frac{K-1}{K}R^m.\end{aligned}$$

Thus, as $\phi \to 1$, marginal consumer surplus (13) converges to

$$\lim_{\phi\to 1}\frac{dCS_\phi^K}{d\phi} = \lim_{\phi\to 1}\frac{(K-1)\phi+1}{(K-1)\phi}\frac{CS\left(\underline{p}(\phi)\right)-CS_\phi^K}{(1-\phi)} = R^m. \qquad (18)$$

Ex ante **expected welfare**

Recall equation (6), representing expected welfare before entry:

$$\mathbf{E}[CS] = N\varepsilon(1-\varepsilon)^{N-1}CS^m + \sum_{K=2}^{N}\binom{N}{K}\varepsilon^K(1-\varepsilon)^{N-K}CS_\phi^K.$$

The corresponding marginal impact of transparency is hence given by

$$\begin{aligned}
\frac{d\mathbf{E}[CS]}{d\phi} &= \frac{\partial \mathbf{E}[CS]}{\partial \varepsilon}\frac{d\varepsilon}{d\phi} + \frac{\partial \mathbf{E}[CS]}{\partial \phi} \\
&= \left[N(1-N\varepsilon)(1-\varepsilon)^{N-2} CS^m\right]\frac{d\varepsilon}{d\phi} \\
&\quad + \left[\sum_{K=2}^{N}\binom{N}{K}(K-N\varepsilon)\varepsilon^{K-1}(1-\varepsilon)^{N-K-1} CS_\phi^K\right]\frac{d\varepsilon}{d\phi} \\
&\quad + \sum_{K=2}^{N}\binom{N}{K}\varepsilon^K(1-\varepsilon)^{N-K}\frac{dCS_\phi^K}{d\phi}. \qquad (19)
\end{aligned}$$

Observe that taking the limit $\phi \to 1$, all expressions that depend on ϕ converge. First, CS_ϕ^K approaches $CS(0)$ for all $K \geq 2$ by Proposition 5 and continuity of $CS(p)$. Second, by equation (18), $dCS_\phi^K/d\phi$ converges to R^m, which holds independently of $K \geq 2$. Third, by equation (11), $\lim_{\phi\to1} d\varepsilon/d\phi$ exists. Fourth and finally, the equilibrium probability of entry converges as well by equation (12). Therefore, we can take the limit $\phi \to 1$ of equation (19) to obtain

$$\begin{aligned}
\lim_{\phi\to1}\frac{d\mathbf{E}[CS]}{d\phi} &= \left[N(1-N\widehat{\varepsilon})(1-\widehat{\varepsilon})^{N-2} CS^m\right]\left(\lim_{\phi\to1}\frac{d\varepsilon}{d\phi}\right) \\
&\quad + \left[\sum_{K=2}^{N}\binom{N}{K}(K-N\widehat{\varepsilon})\widehat{\varepsilon}^{K-1}(1-\widehat{\varepsilon})^{N-K-1} CS(0)\right]\left(\lim_{\phi\to1}\frac{d\varepsilon}{d\phi}\right) \\
&\quad + \sum_{K=2}^{N}\binom{N}{K}\widehat{\varepsilon}^K(1-\widehat{\varepsilon})^{N-K} R^m,
\end{aligned}$$

where again $\widehat{\varepsilon}$ denotes the limit entry probability (12) when $\phi \to 1$.

To simplify the second bracket, we make use of the following two identities,

$$\begin{aligned}
\sum_{K=2}^{N}\binom{N}{K}K\varepsilon^{K-1}(1-\varepsilon)^{N-K-1} &= \frac{N}{1-\varepsilon}\left[1-(1-\varepsilon)^{N-1}\right] \qquad \text{and} \\
N\sum_{K=2}^{N}\binom{N}{K}\varepsilon^{K}(1-\varepsilon)^{N-K-1} &= \frac{N}{1-\varepsilon}\left[1-(1-\varepsilon)^{N}-N\varepsilon(1-\varepsilon)^{N-1}\right],
\end{aligned}$$

which imply

$$\sum_{K=2}^{N}\binom{N}{K}(K-N\varepsilon)\varepsilon^{K-1}(1-\varepsilon)^{N-K-1}$$

$$
\begin{aligned}
&= \frac{N}{1-\varepsilon}\left[1-(1-\varepsilon)^{N-1}\right]-\frac{N}{1-\varepsilon}\left[1-(1-\varepsilon)^{N}-N\varepsilon(1-\varepsilon)^{N-1}\right] \\
&= N(N-1)\varepsilon(1-\varepsilon)^{N-2}.
\end{aligned}
$$

We hence obtain

$$
\begin{aligned}
& \lim_{\phi\to 1}\frac{d\mathbf{E}[CS]}{d\phi} \\
=\ & \left[N(1-N\widehat{\varepsilon})(1-\widehat{\varepsilon})^{N-2}CS^m\right]\left(\lim_{\phi\to 1}\frac{d\varepsilon}{d\phi}\right) \\
& +\left[\sum_{K=2}^{N}\begin{pmatrix} N \\ K \end{pmatrix}(K-N\widehat{\varepsilon})\widehat{\varepsilon}^{K-1}(1-\widehat{\varepsilon})^{N-K-1}CS(0)\right]\left(\lim_{\phi\to 1}\frac{d\varepsilon}{d\phi}\right) \\
& +\sum_{K=2}^{N}\begin{pmatrix} N \\ K \end{pmatrix}\widehat{\varepsilon}^{K}(1-\widehat{\varepsilon})^{N-K}R^m \\
=\ & \left[N(1-N\widehat{\varepsilon})(1-\widehat{\varepsilon})^{N-2}CS^m+N(N-1)\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-2}CS(0)\right] \\
& \times\left(-\frac{1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{N(N-1)\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-2}}\right) \\
& +R^m\left[1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right] \\
=\ & \left[(1-N\widehat{\varepsilon})CS^m+(N-1)\widehat{\varepsilon}CS(0)\right]\left(-\frac{1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{(N-1)\widehat{\varepsilon}}\right) \\
& +R^m\left[1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right] \\
=\ & -(1-N\widehat{\varepsilon})CS^m\frac{1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{(N-1)\widehat{\varepsilon}} \\
& -(CS(0)-R^m)\left[1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right] \\
=\ & -CS^m\frac{1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{(N-1)\widehat{\varepsilon}} \\
& +CS^m\frac{N\left(1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right)}{N-1} \\
& -(CS(0)-R^m)\left[1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right] \\
=\ & -CS^m\left(\frac{1-(1-\widehat{\varepsilon})^{N}-N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{(N-1)\widehat{\varepsilon}}\right)
\end{aligned}
$$

$$
\begin{aligned}
&+CS^m \frac{1-(1-\widehat{\varepsilon})^N - N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{N-1} \\
&+CS^m \left(1-(1-\widehat{\varepsilon})^N - N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right) \\
&-(CS(0)-R^m)\left[1-(1-\widehat{\varepsilon})^N - N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right] \\
= \quad & -\left(\frac{1-(1-\widehat{\varepsilon})^N - N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}}{N-1}\right)\frac{1-\widehat{\varepsilon}}{\widehat{\varepsilon}}CS^m \\
&-\left[1-(1-\widehat{\varepsilon})^N - N\widehat{\varepsilon}(1-\widehat{\varepsilon})^{N-1}\right](CS(0)-CS^m-R^m).
\end{aligned}
$$

Thus, either of the two conditions, $CS(0) - CS^m - R^m > 0$ and $CS^m > 0$, imply a negative impact of transparency on social welfare as long as ϕ is sufficiently close to 1. *Q.E.D.*

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