Too much of a good thing? Welfare consequences of market transparency

by

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November 2, 2013

This paper studies welfare consequences of consumer side market transparency with endogenous entry of firms. Different from most studies, we consider the unique symmetric entry equilibrium, which is in mixed strategies. We identify two effects of market transparency on welfare: a competition effect and a novel market structure effect. We show, surprisingly, that for almost all demand functions the negative market structure effect eventually dominates the positive competition effect as the market becomes increasingly transparent. Consumer side market transparency can therefore be socially excessive even without collusion. The only exception among commonly used demand functions is the set of constant demand functions. (JEL: D43; L13; L15)

1 *Introduction*

Absent concerns of collusion, market transparency is widely considered a good thing. Defined as the share of consumers who are perfectly informed about all available prices, market transparency is thought to intensify price competition among firms, and hence to improve consumer and social welfare in a given market. Moreover, several recent studies unanimously confirmed beneficial effects of market transparency even when firms' entry decisions are included. In this paper, we present a cautionary tale that shows consumer side market transparency can be excessive for both consumer and social welfare under surprisingly general demand conditions on the one hand and a particular mode of firm entry on the other. It is well known that more intense competition in a market (e.g. more firms or price rather than quantity competition) reduces the incentives to enter this market in the first place and that, in consequence, the overall effect of increased competition on social welfare can be negative. However, the recent literature on market transparency does not find such an effect.

*Yiquan Gu (corresponding author), University of Liverpool; Burkhard Hehenkamp, University of Paderborn. We are grateful to Christoph Schmidt for suggesting the title and to Anthony Creane for very helpful discussions. We thank Biung-Ghi Ju and an anonymous referee for valuable suggestions which greatly improved the paper, and participants of the 2011 RES Conference at Royal Holloway, the 9th IIOC in Boston, and the 2011 SIOMS in Chengdu as well as seminar audiences at the Universities of Dortmund, Duisburg-Essen, Heidelberg, Liverpool, Reading and Toulouse School of Economics for helpful comments.

Market transparency in general encompasses all informational aspects of a market. It refers to how well informed market participants are regarding price, quality, availability and/or other characteristics of a product or service. Markets usually display varying degrees of transparency due to costs in transmitting and obtaining information such as search costs of consumers (Diamond, 1971; Stahl, 1989; Armstrong, Vickers, and Zhou, 2009), and possibly also to strategic obfuscation of firms (Ellison and Ellison, 2009; Carlin, 2009). Besides, market transparency has long been a key issue in economic policy, especially since the introduction of the European common market. Notably, measures to improve market transparency formed a central cornerstone in the 1990s when governments started market liberalization in industries such as mail, telecommunication, electricity, gas, etc. In the same decade the advent of the Internet provided increasingly more consumers with simple and cheap ways to learn and compare prices.[1] In consequence, one sees the rise of price-related market transparency in many retail markets.

The welfare effects of market transparency are an important topic to be studied and understood. The prevailing view in the literature can be summarized as follows. If firm collusion is *at debate*, then the overall welfare effect of market transparency is ambiguous. Increased transparency on the firm side increases the scope for coordinated behaviour of firms, and hence is normally considered anti-competitive and welfare damaging (see, e.g., Albaek, Møllgaard, and Overgaard, 1997; Møllgaard and Overgaard, 2001). Increased transparency on the consumer side, on the other hand, allows consumers to make better choices and therefore promotes firm competition and market efficiency in a static setting. However, if firms interact repeatedly and collusion is a concern, consumer side market transparency may either increase or decrease the scope for collusion as it alters both the short-term gain and the long-term punishment to a deviation. (An increase in consumer side market transparency increases a firm's incentive in deviating from a collusion as more consumers will respond to an undercutting price. This effect destabilises a collusion. However, an increase in transparency also increases the magnitude of punishment to a deviant as firm profits under competition are lower in a more transparent market. This effect helps to sustain a collusion. The overall effect is ambiguous. While in Schultz (2005), consumer side market transparency makes a tacit collusion more difficult, Møllgaard and Overgaard (2001) find it can also make a collusion easier.)

However, when firm collusion is *not a concern*, market transparency is found to be unambiguously welfare improving in the literature. In other words, the gain through transparency induced fiercer price competition dominates any potential source of welfare loss. Schultz (2004) studies market transparency in a Hotelling (1929) market with unit consumer demand and quadratic transportation cost. Although with more consumers becoming informed, firms would like to stay further away from each other to soften competition, their incentive to move closer to the competitor to increase market share

[1] It is understood from the endogenous search literature that an increase in the share of consumers with negligible search costs increases the measure of transparency as defined in this paper. See, for example, Stahl (1989) in which consumers with zero search cost become informed of all prices while consumers with high search costs do not search at all. See also the moderate search intensity equilibrium in Janssen and Moraga-González (2004).

dominates. It turns out that market transparency leads to less differentiated products as well as lower prices. In consequence, consumer surplus increases, firm profit decreases, and overall social welfare increases in Schultz (2004).

More closely related to the current paper are the findings in Schultz (2009) and Gu and Wenzel (2011). Both papers build upon the Salop (1979) model of product differentiation with endogenous, long run free entry. Market transparency in such a setting reduces firm profits in the pricing stage for a given number firms. As a result, the number of active firms in the long run is lower in a more transparent market. Due to consumers' preference for variety, a reduction in the number of firms could potentially reduce consumer- as well as social-welfare. However, the efficiency gain from price competition dominates the loss from less variety, and the overall effect of transparency is unambiguously positive. This result is established by Schultz (2009) with unit demand and further confirmed in Gu and Wenzel (2011), where consumer demand exhibits a constant price elasticity following Gu and Wenzel (2009). Price dependent demand in spatial models is studied more generally in Gu and Wenzel (2012a).

Additionally, when firms differ in their marginal costs of production, Gu and Wenzel (2012b) argue that market transparency further selects more productive entrants at the entry stage, and thus presents yet another source of efficiency improvement. Boone and Potters (2006) investigate a different type of market transparency defined as the share of consumers who are aware of all available varieties of a differentiated product. With firms competing in quantities, the authors show that under certain conditions consumer surplus may fall as market transparency rises. However, it still holds that social welfare always increases in market transparency.[2]

In this paper we show that i) market transparency can be socially excessive even without collusion, ii) previous results under endogenous entry depend critically on the mode of market entry, iii) and constant (or unit) demand functions lead to qualitatively different welfare results compared to price-dependent demand schedules. Indeed, when potential entrants enter the market simultaneously, in the unique symmetric equilibrium (which is in mixed strategies), both social welfare and consumer welfare *eventually* decrease as market transparency rises, for almost all demand functions. The only exception is the class of constant demand functions for which market transparency unambiguously improves welfare.

To derive these results, we develop a simple two-stage model where, at stage 1, potential entrants simultaneously decide whether or not to enter a homogeneous product market by paying a fixed cost of entry and where, at stage 2, actual entrants compete in prices. Following Varian (1980) and Schultz (2009), only a fraction of the consumers

[2]Hviid and Møllgaard (2006) study transparency in an intermediate goods market where transaction terms are negotiated between one upstream seller and two independent, differentially informed, downstream buyers. Improved transparency prompts the ill-informed buyer to take a tougher bargaining stand but it may also lead the seller to do the same with the informed buyer. Welfare effects of improved transparency are thus found ambiguous. The current paper differs substantially from theirs in that we focus on supply side competition and market entry.

is informed about prices of all actual entrants. The rest is uninformed and randomly buys from each of the available firms with identical probability. The share of informed consumers is our measure of market transparency. When the market becomes more transparent, active firms compete more aggressively in the second stage and profits are reduced. As a consequence, entry becomes less attractive and the symmetric equilibrium entry probability of potential entrants decreases.

We note that for markets with long development times (e.g. due to R&D investments) or markets where newly and unexpected business opportunities have sprung up (like the Eastern European markets when unexpectedly the Berlin wall came down), potential entrants have to make decisions without knowing others' choices, and therefore the simultaneous entry model and its unique symmetric equilibrium are particularly relevant.

Compared to an asymmetric equilibrium, considering a symmetric entry equilibrium has the following additional advantages. First, given that we study the symmetric pricing equilibrium at the second stage, conceptually it is natural to study the symmetric entry equilibrium at the first stage too. After all, it is not clear why a potential entrant's equilibrium strategy should be different from that of another. Second, there are cases where firms enter a market but fail to repay their entry costs and cases where no firm enters a profitable market.[3] One would argue that a mixed strategy entry equilibrium can explain such observations much better than a pure strategy equilibrium. Finally, a symmetric entry equilibrium also allows us to avoid the integer problem associated with an asymmetric equilibrium. For a more detailed discussion on pure vs. mixed strategies of market entry, see Dixit and Shapiro (1986).

In terms of welfare, we identify two effects of market transparency. Firstly, for any second stage oligopoly, market transparency drives product price closer to the marginal cost of production, and hence increases market efficiency for a given number of oligopolists. This direct *competition effect* of market transparency is positive. Secondly, market transparency decreases the entry probability of potential entrants which in turn increases the probability of a "market breakdown" and decreases the probability of having an oligopoly. This previously overlooked, indirect *market structure effect* of market transparency is negative for almost all demand functions. Unlike the indirect welfare effect resulting from less variety in Schultz (2009) and in Gu and Wenzel (2011), the negative market structure effect almost always dominates the positive competition effect when the market becomes sufficiently transparent. The only exception are the cases where compared to a monopoly there is i) *neither* any consumer welfare loss in a market breakdown ii) *nor* any social welfare benefit in having an oligopoly. The former mutes the impact of not having a market at all and the latter the impact of a lower prob-

[3]For instance, in the movie market, there have been many films that have made huge financial losses possibly due to too many competing titles in the same genre with close release dates. An example would be the 1946 classic *It's a Wonderful Life* which, according to Jewell and Harbin (1982), recorded a loss of $525,000 at the box office. One of the reasons for the loss might have been tough competition from films like *The Best Years of Our Lives* and *Miracle on 34th Street*. On the other hand, however, we sometimes also see no new movies being offered in a certain genre in a certain period of time.

ability of having price competition. Among those demand schedules commonly used in the literature, *only* the class of constant demand functions gives rise to a universally positive effect of market transparency when entry strategies are symmetric.

Our findings can be viewed in the following perspectives. Firstly, they provide a cautionary tale about potential negative welfare consequences of market transparency even when collusion is impossible. While many studies assume market existence and firm competition as given, we show that the novel market structure effect of market transparency resulting from mixed strategies of entry deserves its due attention. Extra caution is needed when giving transparency-related policy recommendations.

Secondly, we relate our result to the more traditional debate on dynamic efficiency of market competition. It is well understood that more intense competition need not be welfare improving when dynamic aspects such as innovation, market entry/exit, etc. are considered. For instance, in a standard homogeneous product market a switch from Cournot to Bertrand competition may reduce welfare when firms have to cover their entry costs. In our model, market competition becomes more intense as transparency rises and converges to standard Bertrand competition in the limit of full transparency. We examine the relationship between market transparency and its dynamic efficiency in the neighbourhood of full transparency where entry is smoothly affected by market competition. Our main result shows that more market transparency can harm social welfare which is in line with findings from the dynamic efficiency literature but surprising to the transparency literature.

Thirdly, it should be duly noted that our result, because of its generality, is a limit result in nature. It says when a market approaches to full transparency, the marginal impact of market transparency on social welfare is negative. As our example in Section 5.4 suggests, the exact optimal level of market transparency varies with different model parameters. There is no doubt that better information among consumers improves the functioning of non-transparent markets.

Last but not least, it is worth noting that our finding complements the recent overhaul of traditional results led by Etro (2006, 2008, 2011a,b) which takes into account that market structures are usually endogenously determined.[4] We show that the market structure effect of market transparency leads to surprising results that are absent in an exogenous market structure.

The rest of the paper is organized as follows. Section 2 sets up the model. In Section 3, we identify equilibrium pricing strategies at stage 2 and introduce the competition effect of market transparency. Firms' equilibrium entry strategies and the market structure effect of market transparency are presented in Section 4. In Section 5, we carry out the analysis of ex ante social welfare, deliver our main theorem, and discuss exceptional cases and optimal transparency. Concluding remarks are offered in Section 6 and the proof of the theorem appears in the Appendix.

[4]The authors thank Anthony Creane for pointing out this connection.

2 The model

2.1 Market transparency and consumer demand

We consider a homogeneous product market with endogenous entry. On the demand side, there is a measure 1 of consumers. Following Varian (1980), a share $\phi \in [0,1]$ of them is informed, i.e., they know all prices quoted in the market. The rest is uninformed. The share of informed consumers, ϕ, is our measure of market transparency and assumed common knowledge.

Informed consumers buy from the firm that charges the lowest price. If there are several, these firms share the demand evenly. Uninformed consumers, on the other hand, cannot compare prices and randomly buy from each of the available firms with identical probability.[5] Therefore, in expectation, all available firms receive an equal share of uninformed consumers.

Individual demand is identical across all consumers which is given by a measurable and integrable function $D(p)$, mapping non-negative prices $p \in [0, \infty)$ into non-negative demand $D \in [0, \infty)$. We assume that the associated revenue function, $R(p) := p \cdot D(p)$, attains a unique global maximum, $R^m := R(p^m) > 0$, at some price $p^m > 0$. Furthermore, $D(p)$ is assumed non-increasing and continuous on $[0, p^m]$.

Central to our welfare analysis is consumer surplus,

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

We note that $CS(p)$ is well defined and finite for any price $p \in [0, \infty)$ as $D(p)$ is assumed measurable and integrable. Moreover, $CS(p)$ is continuously differentiable on $[0, p^m]$ by the continuity of $D(p)$ on $[0, p^m]$.

2.2 The market game

The market game consists of two stages. At stage 1, $N \geq 2$ identical firms, or *potential* entrants, simultaneously and independently decide whether or not to enter the market. Entry costs $f > 0$. In a slight abuse of notation, let $\mathcal{N} := \{1, \ldots, N\}$ denote the corresponding set of potential entrants. At stage 2, entry costs are sunk. Knowing the firms that have entered at stage 1, *actual* entrants compete in prices for informed consumers. Let $\mathcal{K} := \{1, \ldots, K\}$ denote the corresponding set of actual entrants (after appropriate relabelling). Then, each entrant $i \in \mathcal{K}$ chooses a non-negative price $p_i \in \mathcal{P} := [0, \infty)$. We assume that all firms have an identical constant marginal cost of production which is normalized to zero, and that all firms are profit maximizers. Then, p^m is the price a monopolist would charge.

Entry cost f satisfies:

$$\frac{R^m}{N} < f < R^m. \tag{1}$$

[5] For an analysis of Bertrand preferences of this type, see, e.g., Hehenkamp (2002).

The first inequality reflects that not all firms can profitably enter the market at the same time, even if they all set the monopoly price. The second inequality ensures that one firm alone would always find it profitable to supply the market. We note, however, that for a given level of market transparency $\phi \in [0, 1]$, our equilibrium results require only that $f \in ((1 - \phi)R^m/N, R^m)$, which is weaker than (1), especially when ϕ is large.[6] For our limit welfare result to hold, $f \in (0, R^m)$ suffices. Condition (1) is imposed to rule out trivial outcomes, and is made conservative to facilitate a smooth change in equilibrium outcome when market transparency alters.

3 Equilibrium analysis: stage 2 pricing behaviour

Given the symmetric nature of the model, we seek for a symmetric equilibrium. According to the assumption on the fixed cost of entry f, at the first stage of market entry a symmetric equilibrium must be in mixed strategies. Using backward induction, in this section we first analyse stage 2 subgames. Also in this section, we introduce the competition effect of market transparency.

Three qualitatively different market structures can emerge at stage 2, depending on the number of actual entrants, K. First, there can be no actual entrant and the market does not come into existence. Second, one firm has entered and this firm enjoys a monopoly position. Third, two or more firms have entered and the market forms an oligopoly.

3.1 Market breakdown and monopoly

When no firm enters, i.e., $K = 0$, the market breaks down, and consumer surplus is zero. For consumers, this is the worst case. When $K = 1$, the monopolist charges the monopoly price p^m, realizing a revenue of R^m. That all consumers buy from the monopolist at p^m leads to a relatively low consumer surplus $CS^m := CS(p^m)$. The market outcomes in these two cases do not directly depend on market transparency ϕ.

3.2 Oligopoly

When $2 \leq K \leq N$ firms have entered the market at stage 1, they compete in prices for informed consumers at stage 2. Since the entrants charging the lowest price share the demand of informed consumers evenly, and since all entrants share the demand of uninformed consumers equally, the revenue function of entrant $i \in \mathcal{K}$ is given by

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

[6] We will see later in Proposition 2 that an entrant receives a revenue of $(1 - \phi)R^m/K$ at the second stage after $2 \leq K \leq N$ firms have entered. Therefore, when $f > (1 - \phi)R^m/N$, not all N firms can profitably enter the market.

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

We now further distinguish three scenarios according to the level of market transparency. Firstly, when all consumers are uninformed ($\phi = 0$), effectively there is no competition among the K entrants. Each of them receives a share of $1/K$ consumers and charges p^m to obtain a revenue of R^m/K. Consumer surplus corresponds to that of the monopoly case, $CS^K_{\phi=0} = CS(p^m)$, where for CS the superscript K represents the number of actual entrants and the subscript indicates the level of market transparency.

Secondly, when all consumers are perfectly informed ($\phi = 1$), the pricing game reduces to a standard Bertrand oligopoly. In any equilibrium, at least two firms price at the marginal cost of production, and all consumers buy at this price. Therefore, all K entrants earn zero revenue, and consumer surplus is at its maximum, $CS^K_{\phi=1} = CS(0)$.

Finally, when $\phi \in (0, 1)$, there exists no pricing equilibrium in pure strategies.

Lemma *If $2 \leq K \leq N$ and $\phi \in (0,1)$, there exists no stage 2 pricing equilibrium in pure strategies.*

This is a standard result in models with intermediate levels of market transparency.[7] See, for example, Varian (1980) and Rosenthal (1980). The intuition is the following. Like in a standard Bertrand model, firms have an incentive to undercut each other. Unlike in a Bertrand model, however, pricing at marginal cost is *strictly* dominated by charging the monopoly price and receiving monopoly revenue from one's own share of uninformed consumers. As a result, there exists no pure strategy pricing equilibrium.

Nevertheless, there exists a unique symmetric equilibrium which is in mixed strategies. In this equilibrium all K actual entrants adopt a common cumulative distribution function (cdf) $H^K(p) := \Pr\{P \leq p\}$.

Proposition 1 (Rosenthal, 1980) *Suppose there are $2 \leq K \leq N$ firms in the market at stage 2 and market transparency is intermediate, $\phi \in (0,1)$. Let $\underline{p}^K$ be defined by*

$$\underline{p}^K := \inf \left\{ p \in [0, p^m] : \left(\frac{1-\phi}{K} + \phi \right) R(p) = \frac{1-\phi}{K} R^m \right\}, \tag{2}$$

and let

$$H^K(p) := \begin{cases} 0 & \text{for } p < \underline{p} \\ 1 - \inf\limits_{\underline{p} \leq p' \leq p} \left(\frac{1-\phi}{K\phi} \frac{R^m - R(p')}{R(p')} \right)^{\frac{1}{K-1}} & \text{for } \underline{p} \leq p \leq p^m \\ 1 & \text{for } p > p^m \end{cases}. \tag{3}$$

Then the strategy profile $(H^K, \ldots, H^K)$ represents the unique symmetric Nash equilibrium of the K-firm oligopoly pricing game at stage 2.

[7] Omitted standard proofs are available from the authors upon request.

We note first that this result follows directly from Rosenthal (1980) if we let Rosenthal's captive market demand of each firm be $((1-\phi)/K)D(p)$ and the common market demand be $\phi D(p)$.[8] The intuition for this result is that a firm can always guarantee itself at least a revenue of $((1-\phi)/K)R^m$ by charging the monopoly price p^m and giving up on competing for informed consumers. In the symmetric mixed strategy equilibrium, the expected revenue at any price in the support should be the same as $((1-\phi)/K)R^m$. In particular, this condition pins down the lower bound of the support at which a firm receives both its own share of uninformed consumers and all informed consumers.

Second, this symmetric mixed equilibrium strategy, $H^K(p)$, converges in probability to marginal cost pricing when the market approaches full transparency ($\phi \to 1^-$), and to monopoly price pricing when the market approaches no transparency at all ($\phi \to 0^+$).[9] Hence, our model behaves smoothly at the boundaries of full and no transparency, respectively.

Third, in the symmetric mixed strategy equilibrium each actual entrant earns an expected revenue of $((1-\phi)/K)R^m$. The rent from informed consumers is completely competed away. On the demand side, each uninformed consumer buys at a price drawn from the distribution given by the firms' symmetric pricing strategy. Informed consumers, on the other hand, can compared the K realized prices and pick the lowest. Therefore, an informed consumer buys at the minimum price of all entrants which is the first order statistic of K random variables independently chosen from the distribution H^K. The following proposition summarises.

Proposition 2 *Suppose $2 \le K \le N$ and $\phi \in (0,1)$. Then in the second stage K-firm oligopoly,*

(i) an actual entrant's expected revenue is $((1-\phi)/K)R^m$ and

(ii) the expected consumer surplus is

$$CS_\phi^K = \phi \int_{\underline{p}^K}^{p^m} CS(p)dH_{(1)}^K(p) + (1-\phi)\int_{\underline{p}^K}^{p^m} CS(p)dH(p), \tag{4}$$

where $H_{(1)}^K(p)$ denotes the cdf of first order statistic of the K independently distributed prices.

3.3 Competition effect of market transparency

We end our analysis of stage 2 by highlighting the competition effect of market transparency. For a given oligopoly, market transparency makes price competition more intensive and indeed "lowers" equilibrium prices, in terms of first order stochastic dominance. Consequently, the expected consumer surplus increases as the market becomes

[8]Note, however, that when the degree of market transparency changes, the relative size of the captive and the common market does so too.

[9]Weak convergence can be easily shown, using the equilibrium strategy derived in Proposition 1. Convergence in probability is implied because the limit distribution has all probability on a single price (i.e., because the corresponding limit random variable is a constant).

more transparent in a given oligopoly. This is the *competition effect* of market transparency.

PROPOSITION 3 *Suppose $2 \leq K \leq N$ and $\phi \in (0,1)$. The more transparent the market (the higher ϕ), the lower an entrant's price, the lower the minimum price of all entrants (both in terms of first order stochastic dominance), and the higher the expected consumer surplus, CS^K_ϕ.*

PROOF First, the complementary probability $\widehat{H}^K(p) := 1 - H^K(p)$, considered as function of ϕ, clearly decreases in ϕ. Hence, a pricing strategy $H^K(p)$ corresponding to a lower market transparency ϕ' first order stochastically dominates another that corresponds to some larger degree of market transparency ϕ'', for any $0 < \phi' < \phi'' < 1$.

Second, the distribution of the first order stochastic, $H^K_{(1)}(p)$, inherits all stochastic monotonicity properties from its parent distribution, $H^K(p)$ (see David and Nagaraja, 2003, Theorem 4.4.1).

Finally, consumer surplus $CS(p)$ is a bounded, continuous, and strictly decreasing function of p on the interval $[0, p^m]$. The final claim hence follows from Theorem 1.A.3 in Shaked and Shanthikumar (2007). *Q.E.D.*

4 Equilibrium analysis: stage 1 entry decisions

Having analysed the equilibrium behaviour at stage 2, we now proceed to investigate the entry decision of a potential entrant at stage 1. Again, we confine our analysis to symmetric equilibria. Given the results in Proposition 2, we note that the characterization of the mixed strategy entry equilibrium is relatively straightforward. Later in this section, we detail the market structure effect of market transparency.

4.1 Symmetric entry equilibrium

First, note that there is no symmetric equilibrium in pure strategies.[10] Second, we show that the unique symmetric entry equilibrium is in mixed strategies.

Let $\varepsilon \in (0,1)$ denote the symmetric *probability of entry*. In equilibrium, each firm must be indifferent between 'entry' and 'no entry'. Since 'no entry' entails an expected payoff of zero, 'entry' does so too:

$$\underbrace{(1-\varepsilon)^{N-1}}_{\text{Prob. of a monopoly}} R^m + \sum_{j=1}^{N-1} \underbrace{\binom{N-1}{j} \varepsilon^j (1-\varepsilon)^{N-1-j}}_{\text{Prob. of a (j+1)-oligopoly}} \underbrace{\frac{(1-\phi) R^m}{j+1}}_{\text{(j+1)-oligopoly revenue}}$$

[10]Recall that $f \in (R^m/N, R^m)$. If all firms enter, they incur losses because $(1-\phi)R^m/N \leq R^m/N < f$. Hence, for any firm, 'no entry' would be strictly better than 'entry' (given that all other firms stick with 'entry'). If no firm enters, entry is profitable because $R^m > f$ (given that all other firms stay out of the market).

$$(5) \qquad \qquad - \underbrace{f}_{\text{Entry cost}} = \underbrace{0}_{\text{Payoff of 'no entry'}} .$$

The first two items in (5) represent the expected revenue of entry. Given that the other $(N-1)$ firms enter the market independently with probability ε, by entry a firm enjoys the monopoly position and earns the monopoly revenue R^m with the probability of $(1-\varepsilon)^{N-1}$. With the probability of $\binom{N-1}{j}\varepsilon^j(1-\varepsilon)^{N-1-j}$, j other firms enter and the market becomes a $(j+1)$-oligopoly. In such a case, 'entry' yields an expected revenue of $(1-\phi)R^m/(j+1)$ (see Proposition 2). The overall expected revenue of 'entry' net of entry cost f should be equal to the payoff of 'no entry' which is zero.

It's easily verified that when an $\varepsilon \in (0,1)$ satisfies equation (5), it identifies a symmetric entry equilibrium at stage 1. Indeed, we have the following result where (6) is a simplified version of (5).

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

$$(6) \qquad \phi(1-\varepsilon)^{N-1} + \frac{1-\phi}{N\varepsilon}\left[1-(1-\varepsilon)^N\right] = \frac{f}{R^m}.$$

Proof We first show that (6) can be derived from (5). We then show that, for any $\phi \in [0,1]$, there exists a unique $\varepsilon \in (0,1)$ that satisfies (6). The rest follows straightforwardly from the characterization of mixed strategy equilibrium (see, e.g., Osborne, 2009, chap. 4).

We note the following two identities:

$$\sum_{j=1}^{N-1}\binom{N-1}{j}\frac{\varepsilon^j(1-\varepsilon)^{N-1-j}}{j+1} = \frac{1}{N\varepsilon}\sum_{j=2}^{N}\binom{N}{j}\varepsilon^j(1-\varepsilon)^{N-j} \text{ and}$$

$$1 = [\varepsilon + (1-\varepsilon)]^N = \sum_{j=0}^{N}\binom{N}{j}\varepsilon^j(1-\varepsilon)^{N-j}.$$

Using these two identities, condition (5) can be simplified to

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

and further easily to (6).

Fix a $\phi \in [0,1]$ and let V denote the left-hand side of (6). To establish the existence of a unique $\varepsilon \in (0,1)$ that satisfies (6), we note first that V is a continuous and differentiable function of ε. Second,[11]

$$(7) \qquad \frac{dV}{d\varepsilon} = -\phi(N-1)(1-\varepsilon)^{N-2} - (1-\phi)\frac{1-N\varepsilon(1-\varepsilon)^{N-1}-(1-\varepsilon)^N}{N\varepsilon^2} < 0.$$

[11]Note that $1 = \sum_{j=0}^{N}\binom{N}{j}\varepsilon^j(1-\varepsilon)^{N-j} > N\varepsilon(1-\varepsilon)^{N-1} + (1-\varepsilon)^N$.

Third, V approaches 1 as $\varepsilon \to 0$ and approaches $(1-\phi)/N$ as $\varepsilon \to 1$. And finally, from condition (1) on the entry cost, we have

$$\frac{1-\phi}{N} \leq \frac{1}{N} < \frac{f}{R^m} < 1.$$

By the intermediate value theorem, there hence exists a unique $\varepsilon \in (0,1)$ that satisfies (6). *Q.E.D.*

4.2 Market structure effect of market transparency

Intuitively, when the market becomes less profitable, firms have a smaller incentive to enter, and therefore the equilibrium entry probability ε should decrease. In the current framework, the market can become less profitable for two reasons: a higher level of market transparency and a higher entry cost per unit of monopoly revenue.

PROPOSITION 5 *Entry is the less likely (the smaller ε),*

(i) the more transparent the market (the larger ϕ), and/or
(ii) the higher the ratio of entry cost and monopoly revenue (the larger f/R^m).

PROOF From (7) in the previous proof we know $dV/d\varepsilon < 0$. Therefore, claim ii) follows. Moreover,

$$\frac{dV}{d\phi} = -\frac{1 - N\varepsilon(1-\varepsilon)^{N-1} - (1-\varepsilon)^N}{N\varepsilon} < 0. \tag{8}$$

By the implicit function theorem, we have $dV/d\varepsilon < 0$ and hence, claim i) follows. *Q.E.D.*

Central to our welfare analysis is the impact of market transparency on the equilibrium probability of entry. When a market becomes more transparent, price competition becomes more intensive and consequently, the equilibrium entry probability decreases. A *lower* entry probability in turn has two effects: i) the probability of market non-existence, $(1-\varepsilon)^N$, *increases*; ii) the probability of having an oligopoly, $1-(1-\varepsilon)^N - N\varepsilon(1-\varepsilon)^{N-1}$, *decreases*.[12] This is what we call the *market structure effect* of market transparency. To summarise:

PROPOSITION 6 *The more transparent the market, the more likely there is no ex post entry, and the less likely there is ex post price competition.*

[12] Note that

$$\frac{d\left(1-(1-\varepsilon)^N - N\varepsilon(1-\varepsilon)^{N-1}\right)}{d\varepsilon} = N(N-1)\varepsilon(1-\varepsilon)^{N-2} > 0.$$

5 *Social welfare*

In this section we present our main result: for almost all demand functions, social welfare eventually decreases in market transparency. In this sense, market transparency can indeed be excessive, and full transparency is almost always suboptimal. As the proof of the main result is rather complicated, it appears in the Appendix and we instead focus on the underlying intuition in this section. We will also discuss the special case of constant demand functions and the socially optimal level of market transparency.

5.1 *Social welfare and market transparency*

Social welfare consists of two parts: firm profits and consumer surplus. However, in expectation, all N potential entrants earn zero profits. Therefore, expected social welfare and expected consumer surplus coincide. Ex ante, there are three different market structures at stage 2: market breakdown, monopoly, and oligopoly. Consumer surplus is zero when no firm has entered at stage 2, CS^m in a monopoly, and CS_ϕ^K in a K-firm oligopoly. Letting W denote the ex ante expected social welfare, we have

$$W = \underbrace{(1-\varepsilon)^N}_{\text{Prob. of no entry}} 0 + \underbrace{N\varepsilon\,(1-\varepsilon)^{N-1}}_{\text{Prob. of a monopoly}} CS^m + \sum_{K=2}^{N} \underbrace{\binom{N}{K}\varepsilon^K\,(1-\varepsilon)^{N-K}}_{\text{Prob. of a }K\text{-oligopoly}} CS_\phi^K, \tag{9}$$

where CS_ϕ^K is defined in equation (4).

From (9), we can clearly see the two effects of market transparency ϕ on social welfare. First, in a given oligopoly, the *positive* competition effect of market transparency increases consumer surplus CS_ϕ^K (see Proposition 3). Second, through a lower equilibrium entry probability, the market structure effect of market transparency increases the probability of market breakdown and reduces the probability of an oligopoly (see Proposition 6). As $CS_\phi^K \geq CS^m \geq 0$, this market structure effect is usually *negative.* In general, the overall effect of market transparency can be in either direction depending on which effect dominates the other. However, it can be shown that in the limit as ϕ approaches 1, for almost all demand functions, the negative market structure effect dominates the positive competition effect.

5.2 *Too much of a good thing*

To make the point precise, our objective here is to show that $\lim_{\phi\to 1^-} dW/d\phi < 0$. To this end, we make the following simplifying assumption on the demand function $D(p)$.

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

Regarding this assumption, several remarks are in order. First, the differentiability of $D(p)$ is needed only for the differentiability of social welfare W; it is not needed throughout our equilibrium analysis. Second, that $R'(p)$ is strictly larger than zero ensures the differentiability of the second stage pricing equilibrium $H^K(p)$ which is required for the differentiability of social welfare.[13] Third, $\lim_{p\to 0^+} pD'(p) = 0$ is a very mild assumption. It would have been natural to impose the more demanding requirement that the resulting increase in demand is bounded as price approaches marginal cost. However, we can do better and allow for $\lim_{p\to 0^+} D'(p) = -\infty$ as long as p converges to 0 faster than $D'(p)$ goes to $-\infty$.

Theorem *Let Assumption (D) be met. Social welfare W decreases with market transparency ϕ for ϕ sufficiently large, i.e.,* $\lim_{\phi\to 1^-} dW/d\phi < 0$*, if either of the following two conditions holds (or both):*

$$i)\ CS^m > 0; \quad ii)\ CS(0) - CS^m - R^m > 0.$$

This theorem identifies two conditions on the demand function each as sufficient for market transparency to unambiguously decrease social welfare when ϕ approaches 1. The first condition requires the consumer surplus at the monopoly price, $CS^m = \int_{p^m}^{\infty} D(\tilde{p})d\tilde{p}$, to be strictly larger than zero. The second condition says that the deadweight loss associated with a monopoly relative to perfect competition, $CS(0) - CS^m - R^m = \int_0^{p^m} [D(\tilde{p}) - D(p^m)]\, d\tilde{p}$, is strictly positive.

The intuition of this result is as follows. The market structure effect of market transparency is detrimental to social welfare because it increases the probability of market non-existence and decreases the probability of an oligopoly. If there is neither any consumer welfare loss in a market breakdown ($CS^m = 0$) nor any social welfare benefit in having price competition ($CS(0) = CS^m + R^m$), changes in the probabilities of different market structures naturally become benign to social welfare.

Both conditions could easily be replaced by direct requirements on the primitive demand function. For instance, condition i) would be implied if $D(p)$ were assumed continuous at p^m from both sides and condition ii) would follow if $D(p)$ were assumed *strictly* decreasing at some price $p \in (0, p^m)$. However, we think our current characterization of the two conditions is more intuitive.

It is also evident from this discussion that for almost all demand functions, at least one of the two conditions holds. Therefore, our finding that market transparency becomes socially excessive when market is sufficiently transparent is robust.

A detailed proof of this theorem appears in Appendix 6. As the stage 2 oligopolistic pricing equilibrium converges to marginal cost pricing when the market becomes increasingly transparent, our main challenge there is to show that the marginal impact of transparency on consumer surplus in a given oligopoly is bounded and that $\lim_{\phi\to 1^-} dCS_\phi^K/d\phi$ exists for $2 \le K \le N$.

5.3 The special case of constant demand functions

For demand functions that satisfy neither of the two conditions in the theorem, i.e., for those such that $CS^m = 0$ and $CS(0) = R^m$, the marginal impact of market transparency

[13] Note that this condition eliminates the need for the infimum operators in (2) and (3).

on social welfare $dW/d\phi$ converges to 0 as $\phi \to 1^-$, rather than to a negative value (see equation (29) in the Appendix). The *only* demand functions permitted in the current analysis that satisfy both $CS^m = 0$ and $CS(0) = R^m$ are constant demand functions of the type[14]

$$D(p) = \begin{cases} a & \text{if } p \in [0, p^m] \\ 0 & \text{if } p > p^m \end{cases} , \tag{10}$$

where $p^m, a > 0$.

Indeed, for demand functions such as (10), there exists a tractable representation of social welfare and one can verify that market transparency is unambiguously welfare improving for all $\phi \in (0,1)$ and that the marginal effect goes to zero as $\phi \to 1^-$. Therefore, using a constant demand function leads to a qualitatively different and, more importantly, exceptional welfare result compared to using a more general price dependent demand schedule.

For example, in a model of product differentiation with a unit demand function (i.e., $a = 1$), Schultz (2009) investigates the case of an 'almost homogeneous market' by taking the limit of transportation cost to zero. The rest of the setup is comparable to ours. It is found that social welfare always increases in market transparency. However, we have just learned that this finding cannot be generalized to any other more general price dependent demand function.

5.4 Optimal transparency

Our theorem implies that for almost all demand functions, full transparency is socially excessive. However, it is silent on the exact level of optimal market transparency. In this section, we present an example to gain further understanding on optimal transparency in the current framework. We demonstrate that the negative market structure effect can be quite pronounced and that the optimal market transparency can be quite low.

Example. Consider a market with a simple linear demand function, $D(p) = 1 - p$ for $p \in [0,1]$. The monopoly revenue R^m is hence $1/4$. Let there be two potential entrants, i.e., $N = 2$. We further consider two cases.

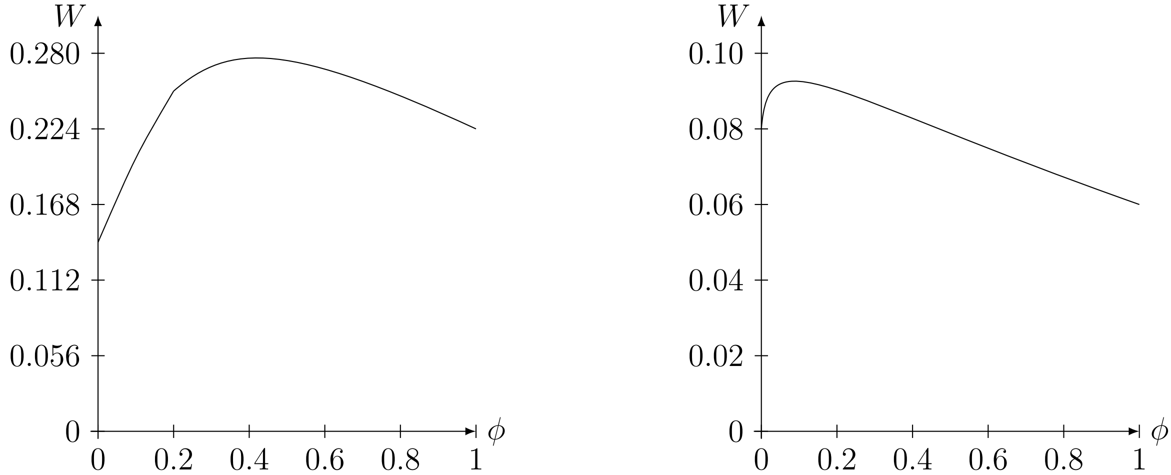
First, let $f = 1/10$. When $\phi > 1/5$, the symmetric entry is in mixed strategies and our theorem applies.[15] When $\phi \leq 1/5$, both firms can enter without incurring losses. With both firms entering the market with certainty, the market structure effect is absent and market transparency increases social welfare through its positive competition effect. Figure 1(a) represents social welfare W as a function of market transparency ϕ. We note that market transparency increases social welfare even after the market structure

[14] As we assume neither continuity nor differentiability of a demand function for $p > p^m$, it is theoretically possible to have $D(p) > 0$ for some $p > p^m$ while still having $CS^m = 0$. Such trivial cases are not sufficiently interesting.

[15] See the discussion after condition (1) in section 2.2.

effect becomes present ($\phi = 0.2$). It, however, eventually decreases social welfare and the optimal level of transparency seems quite low in this particular case.

Second, let $f = 1/5$ instead. Now condition (1) holds and both the positive competition effect and the negative market structure effect are present for all $\phi \in (0, 1)$. Figure 1(b) represents social welfare W for $f = 1/5$. Although the pattern is similar to the previous case, we note that social welfare and the optimal level of market transparency are much lower in this case.[16]



(a) Low entry cost: $f = 1/10$

(b) High entry cost: $f = 1/5$

Figure 1
Social welfare (W) as a function of market transparency (ϕ)

6 *Concluding remarks*

Except for Section 5 in Schultz (2009), papers on welfare consequences of market transparency have largely focused on (asymmetric) long run free entry of firms. Our paper complements the existing literature by providing an account for the case of simultaneous entry.

This half of the picture revealed by the current paper is rather striking given that absent collusion all previous papers find consumer side market transparency universally welfare improving. Indeed, we find that except for the set of constant demand functions, market transparency eventually becomes socially excessive as transparency keeps on rising.

We attribute this surprising negative result to the previously overlooked market structure effect of market transparency: when firms enter with lower probabilities, the market

[16]Numerical simulations for this example indicate a negative relationship between entry cost and the optimal level of transparency.

is more likely to break down and price competition is less likely. In the special case of a constant demand function, however, this market structure effect is inconsequential. This explains the qualitative difference in welfare results between a model with a general price dependent demand function and one with, say, a unit demand function.

Finally, compared to Schultz (2009) and Gu and Wenzel (2011), we would like to note that it is the market structure effect of transparency and not the assumption of product homogeneity that accounts for the current result. In a symmetric entry equilibrium, as long as it does not pay for all potential entrants to enter a fully transparent market, this negative market structure effect of market transparency is present, with or without product differentiation. Of course, product differentiation affects the optimal level of market transparency which we do not know much about from the current analysis. We hope that future research will shed more light on this issue.

Appendix: Proof of the theorem

The plan of this proof is as follows. After some preliminary results, we first investigate the competition effect of market transparency as the market becomes increasingly transparent, i.e., the marginal impact of ϕ on CS_{ϕ}^{K} in any K-firm oligopoly, as $\phi \to 1$.[17] Subsequently, we examine the market structure effect in the limit by evaluating the marginal impact of ϕ on the entry probability ε. Finally, we combine these two effects to show that the total marginal effect of ϕ on *ex ante* expected welfare W is negative in the limit as $\phi \to 1$ if either (or both) of the two conditions in the theorem is met.

A.1 Preliminaries

Consider a K-firm oligopoly with intermediate transparency $\phi \in (0,1)$. By Assumption (D), $R(p)$ strictly increases in p on $(0, p^m)$. Consequently, the equilibrium pricing strategy (3) for $p \in [\underline{p}, p^m]$ reduces to

$$H^K(p) = 1 - \left(\frac{1-\phi}{K\phi} \frac{R^m - R(p)}{R(p)} \right)^{\frac{1}{K-1}}. \tag{11}$$

The corresponding density function is thus

$$h^K(p) = \frac{1-\phi}{K(K-1)\phi} \left(\frac{1-\phi}{K\phi} \frac{R^m - R(p)}{R(p)} \right)^{\frac{2-K}{K-1}} \frac{R^m R'(p)}{R^2(p)}. \tag{12}$$

From (11) and (12), we can derive the distribution of the minimum price among the K entrants and its density, respectively,

$$H_{(1)}^K(p) = 1 - \left(1 - H^K(p)\right)^K,$$
$$h_{(1)}^K(p) = K \left(1 - H^K(p)\right)^{K-1} h^K(p).$$

[17] For conciseness, we write $\phi \to 1$ instead of $\phi \to 1^-$ in this appendix.

To determine consumer surplus further below, we combine the above two distributions, weighing them with the share of informed and uninformed consumers, respectively. The corresponding density and its derivative regarding ϕ read

$$\begin{aligned}\overline{h}^K(p) &:= \phi h^K_{(1)}(p) + (1-\phi)h^K(p)\\ &= \frac{(1-\phi)^2}{K(K-1)\phi}\frac{(R^m)^2\, R'(p)}{R^3(p)}\left(\frac{1-\phi}{K\phi}\frac{R^m - R(p)}{R(p)}\right)^{\frac{2-K}{K-1}}\\ &= \frac{(1-\phi)R^m}{R(p)}h^K(p) \qquad (13)\end{aligned}$$

and

$$\frac{d\overline{h}^K(p)}{d\phi} = -\frac{(K-1)\phi+1}{(K-1)\phi(1-\phi)}\overline{h}^K(p). \qquad (14)$$

From (2), the lowest price $\underline{p}^K$ in the support is implicitly defined by

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

Using total differentiation,

$$\frac{d\underline{p}^K}{d\phi} = -\frac{K}{[(K-1)\phi+1]^2}\frac{R^m}{R'\left(\underline{p}^K\right)}. \qquad (15)$$

Finally, we evaluate the combined density $\overline{h}^K(p)$ at this lower bound of price $\underline{p}^K$:

$$\overline{h}^K\left(\underline{p}^K\right) = \frac{[(K-1)\phi+1]^3}{K(K-1)\phi(1-\phi)}\frac{R'\left(\underline{p}^K\right)}{R^m}. \qquad (16)$$

A.2 Competition effect: consumer surplus in a K-firm oligopoly

When $2 \le K \le N$ firms have entered the market, consumer surplus is given by (4). Using the combined density $\overline{h}^K(p)$,[18]

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

The marginal impact of ϕ on CS^K_ϕ is thus given by

$$\frac{dCS^K_\phi}{d\phi} = -CS\left(\underline{p}(\phi)\right)\overline{h}\left(\underline{p}(\phi)\right)\frac{d\underline{p}}{d\phi} + \int_{\underline{p}(\phi)}^{p^m} CS(p)\frac{d\overline{h}(p)}{d\phi}dp$$

[18] We write $\underline{p}(\phi)$ to highlight $\underline{p}$'s dependence on ϕ. Note that for conciseness the index K associated with $\underline{p}^K$ and $\overline{h}^K(p)$ has been suppressed.

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

$$= \frac{(K-1)\phi+1}{(K-1)\phi}\frac{CS\left(\underline{p}(\phi)\right) - CS_\phi^K}{1-\phi}, \tag{17}$$

where the second equality is obtained by substituting (16) for $\overline{h}\left(\underline{p}(\phi)\right)$, (15) for $d\underline{p}/d\phi$ and (14) for $d\overline{h}(p)/d\phi$.

When $\phi \to 1$, $\underline{p}$ converges to 0 and the symmetric pricing equilibrium $H^K(p)$ converges to a degenerated distribution on the constant 0. Therefore, both $CS\left(\underline{p}(\phi)\right)$ and CS_ϕ^K converge to $CS(0)$, and it is not clear whether $\lim_{\phi\to1}\left(CS\left(\underline{p}(\phi)\right) - CS_\phi^K\right)/(1-\phi)$ exists or not. Since directly applying l'Hôpital's rule does not help, we decompose the second part in (17) into two terms:

$$\frac{CS\left(\underline{p}(\phi)\right) - CS_\phi^K}{1-\phi} = \frac{CS\left(\underline{p}(\phi)\right) - CS(0)}{1-\phi} + \frac{CS(0) - CS_\phi^K}{1-\phi}. \tag{18}$$

We now show that the limits of these two terms exist as $\phi \to 1$. For the first term, we have

$$\lim_{\phi\to1}\frac{CS\left(\underline{p}(\phi)\right) - CS(0)}{1-\phi} = \lim_{\phi\to1}\left(D\left(\underline{p}(\phi)\right)\frac{d\underline{p}(\phi)}{d\phi}\right)$$

$$= \lim_{\phi\to1}\left(D\left(\underline{p}\left(\phi\right)\right)\frac{-K}{\left[\left(K-1\right)\phi+1\right]^2}\frac{R^m}{R'\left(\underline{p}^K\right)}\right)$$

$$= \left(\lim_{\phi\to1}\frac{-KR^m}{\left[\left(K-1\right)\phi+1\right]^2}\right)\left(\lim_{\phi\to1}\frac{D\left(\underline{p}\left(\phi\right)\right)}{D\left(\underline{p}\left(\phi\right)\right)+\underline{p}\left(\phi\right)D'\left(\underline{p}\left(\phi\right)\right)}\right)$$

$$= -\frac{R^m}{K}, \tag{19}$$

where the first equality follows from applying l'Hôpital's rule and the second from equation (15). The last equation holds because by Assumption (D) the second limit is 1.

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

$$\frac{CS(0) - CS_\phi^K}{\left(1-\phi\right)R^m} = \frac{1}{\left(1-\phi\right)R^m}\int_{\underline{p}(\phi)}^{p^m}\left(\int_0^p D\left(\tilde{p}\right)d\tilde{p}\right)\overline{h}\left(p\right)dp$$

$$= \int_{\underline{p}(\phi)}^{p^m}\frac{\left(\int_0^p D\left(\tilde{p}\right)d\tilde{p}\right)}{R\left(p\right)}h\left(p\right)dp = \int_{\underline{p}(\phi)}^{p^m}\Psi\left(p\right)h\left(p\right)dp, \tag{20}$$

where the second equality follows from equation (13) and the third from setting $\Psi(p) := (\int_0^p D\left(\tilde{p}\right)d\tilde{p})/R(p)$ for any price $p \in (0, p^m]$.

We note that by l'Hôpital's rule and Assumption (D),

$$\lim_{p\to0}\Psi(p) = \lim_{p\to0}\frac{D(p)}{D(p)+pD'(p)} = 1.$$

Hence, $\Psi(p)$ is bounded and continuous on $(0, p^m]$, the support of $H(p)$. Now, because the last expression in (20) represents the expected value of $\Psi(p)$ under the probability distribution $H(p)$ which converges in probability to the constant $p = 0$, by the Portmanteau Theorem[19] we obtain

$$\lim_{\phi\to 1} \frac{CS(0) - CS_\phi^K}{(1-\phi)R^m} = \lim_{\phi\to 1} \int_{\underline{p}(\phi)}^{p^m} \Psi(p)h(p)dp = 1. \tag{21}$$

Combining (19) and (21), we obtain the limit of (18) as $\phi \to 1$,

$$\begin{aligned} \lim_{\phi\to 1} \frac{CS\left(\underline{p}(\phi)\right) - CS_\phi^K}{1-\phi} &= \lim_{\phi\to 1} \frac{CS\left(\underline{p}(\phi)\right) - CS(0)}{1-\phi} + \lim_{\phi\to 1} \frac{CS(0) - CS_\phi^K}{1-\phi} \\ &= \frac{K-1}{K} R^m. \end{aligned} \tag{22}$$

Finally, from (17) and (22), we have

$$\lim_{\phi\to 1} \frac{dCS_\phi^K}{d\phi} = \lim_{\phi\to 1} \frac{(K-1)\phi + 1}{(K-1)\phi} \frac{CS\left(\underline{p}(\phi)\right) - CS_\phi^K}{1-\phi} = R^m. \tag{23}$$

We note that this positive marginal impact of market transparency converges to the monopoly revenue as the market becomes increasingly transparent and is independent of the number of entrants K.

A.3 Market structure effect: probability of entry

The equilibrium probability of entry ε is implicitly given by (6). From equations (7), (8) and the implicit function theorem, the marginal impact of market transparency on equilibrium entry probability is

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

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

$$\lim_{\phi\to 1} \frac{d\varepsilon}{d\phi} = -\frac{1 - N\hat{\varepsilon}\left(1-\hat{\varepsilon}\right)^{N-1} - \left(1-\hat{\varepsilon}\right)^N}{N(N-1)\hat{\varepsilon}\left(1-\hat{\varepsilon}\right)^{N-2}}, \tag{24}$$

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

$$\hat{\varepsilon} = 1 - \left(\frac{f}{R^m}\right)^{\frac{1}{N-1}}. \tag{25}$$

We note that $\hat{\varepsilon} \in (0,1)$ as $f \in (R^m/N, R^m)$.

[19] See, e.g., Chapter 1 in Billingsley (1999).

A.4 Ex ante expected welfare

We are now ready to evaluate the overall impact of market transparency on ex ante social welfare as $\phi \to 1$. By (9), we have

$$
\begin{aligned}
\frac{dW}{d\phi} = & \underbrace{\frac{\partial W}{\partial \varepsilon}\frac{d\varepsilon}{d\phi}}_{\text{The market structure effect}} + \underbrace{\frac{\partial W}{\partial \phi}}_{\text{The competition effect}} \\
&= \left[N(1-N\varepsilon)(1-\varepsilon)^{N-2}CS^m\right]\frac{d\varepsilon}{d\phi} \\
&\quad + \left(\sum_{K=2}^{N}\binom{N}{K}(K-N\varepsilon)\varepsilon^{K-1}(1-\varepsilon)^{N-K-1}CS_\phi^K\right)\frac{d\varepsilon}{d\phi} \\
&\quad + \sum_{K=2}^{N}\binom{N}{K}\varepsilon^K(1-\varepsilon)^{N-K}\frac{dCS_\phi^K}{d\phi}. \qquad (26)
\end{aligned}
$$

We note that as $\phi \to 1$, all expressions that depend on ϕ converge. The reasons are as follows. Firstly, CS_ϕ^K approaches $CS(0)$ for all $2 \leq K \leq N$. Secondly, by (23), $dCS_\phi^K/d\phi$ converges to R^m for all $2 \leq K \leq N$. Thirdly, equilibrium probability of entry converges to $\hat{\varepsilon}$. Finally, by (24), $\lim_{\phi\to 1} d\varepsilon/d\phi$ exists. Hence, we can take the limit of (26) as $\phi \to 1$ to obtain

$$
\begin{aligned}
\lim_{\phi\to 1}\frac{dW}{d\phi} &= \left[N(1-N\hat{\varepsilon})(1-\hat{\varepsilon})^{N-2}CS^m\right]\left(\lim_{\phi\to 1}\frac{d\varepsilon}{d\phi}\right) \\
&\quad + \left[\sum_{K=2}^{N}\binom{N}{K}(K-N\hat{\varepsilon})\hat{\varepsilon}^{K-1}(1-\hat{\varepsilon})^{N-K-1}CS(0)\right]\left(\lim_{\phi\to 1}\frac{d\varepsilon}{d\phi}\right) \\
&\quad + \sum_{K=2}^{N}\binom{N}{K}\hat{\varepsilon}^K(1-\hat{\varepsilon})^{N-K}R^m. \qquad (27)
\end{aligned}
$$

To simplify the expression in the second set of square brackets, we make use of the following two identities:

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

Together they imply

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

$$=N(N-1)\varepsilon(1-\varepsilon)^{N-2}. \tag{28}$$

Using (24), (25) and (28), (27) can be reduced to

$$\begin{aligned}
&\lim_{\phi\to 1}\frac{dW}{d\phi}\\
&=\left[N(1-N\hat{\varepsilon})(1-\hat{\varepsilon})^{N-2}CS^m\right]\left(\frac{1-N\hat{\varepsilon}(1-\hat{\varepsilon})^{N-1}-(1-\hat{\varepsilon})^N}{-N(N-1)\hat{\varepsilon}(1-\hat{\varepsilon})^{N-2}}\right)\\
&\left[N(N-1)\hat{\varepsilon}(1-\hat{\varepsilon})^{N-2}CS(0)\right]\left(\frac{1-N\hat{\varepsilon}(1-\hat{\varepsilon})^{N-1}-(1-\hat{\varepsilon})^N}{-N(N-1)\hat{\varepsilon}(1-\hat{\varepsilon})^{N-2}}\right)\\
&+R^m\left[1-N\hat{\varepsilon}(1-\hat{\varepsilon})^{N-1}-(1-\hat{\varepsilon})^N\right]\\
&=-\underbrace{\left(\frac{1-N\hat{\varepsilon}(1-\hat{\varepsilon})^{N-1}-(1-\hat{\varepsilon})^N}{N-1}\right)\frac{1-\hat{\varepsilon}}{\hat{\varepsilon}}}_{>0}\underbrace{CS^m}_{\geq 0}\\
&-\underbrace{\left[1-N\hat{\varepsilon}\left(1-\hat{\varepsilon}\right)^{N-1}-\left(1-\hat{\varepsilon}\right)^N\right]}_{>0}\underbrace{\left(CS(0)-CS^m-R^m\right)}_{\geq 0}.
\end{aligned} \tag{29}$$

Thus, if $CS^m > 0$, or $CS(0) - CS^m - R^m > 0$, or both, $\lim_{\phi\to 1} dW/d\phi < 0$. *Q.E.D.*

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