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Abstract

Can an increasing number of firms and brands exacerbate problems related to asymmetric information on product quality?. This working paper analyzes this trade-off between variety and information using Salop's (1979) framework by introducing quality uncertainty and a simple information diffusion process. As the number of firms increases, the marginal benefits of lower prices and wider product variety may be outweighed by a reduction in consumer information and average quality. Thus, market expansions require a parallel improvement in information mechanisms. Because information has public good characteristics, it is an open question as to how efficiently the market may respond to this requirement.

Key words

Quality, asymmetric information, reputation, horizontal differentiation, market size.

Resumen

¿Puede el incremento del número de empresas acentuar los problemas de información asimétrica sobre la calidad de los productos? Este documento de trabajo analiza el posible *trade-off* entre la variedad de la oferta y la información de los consumidores, utilizando el marco teórico de Salop (1979) en el que se introduce incertidumbre sobre la calidad y un sencillo mecanismo de difusión de la información. Conforme el número de empresas aumenta, los beneficios marginales de precios más bajos y de una mayor variedad de productos se ven superados por una reducción en la información de los consumidores y en la calidad promedio de la oferta. En consecuencia, la expansión y la globalización de los mercados requieren de una mejora en paralelo de los mecanismos de información hacia los consumidores. Dado que la información tiene características de bien público, es una cuestión abierta la eficiencia con la que los mercados responden a esta necesidad.

Palabras clave

Calidad, información asimétrica, reputación, diferenciación horizontal, tamaño de mercado.

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1. Introduction

CAN an increasing number of brands exacerbate problems related to asymmetric information on product quality? If so, then can an increase in the number of firms reduce incentives to produce high-quality goods? Could the (marginal) negative welfare effect of lower expected quality exceed in some markets the (marginal) benefits of lower prices and increased variety that a larger number of firms provides? These questions are important, given that economic growth, globalization, and Internet retailing have produced a vast increase in the number of sellers and brands available to consumers[1].

This working paper is a first step in exploring the potential trade-off between product variety and information, and its welfare consequences. We extend Salop's (1979) model of horizontal differentiation by introducing both uncertainty about product quality and a simple information accumulation process on firm types (i.e., the types determining the probability of producing *lemons*). We keep the model as simple as possible; specifically, there are only two possible product qualities, two types of firms with respect to the probability of producing bad-quality goods, and two periods.

We first consider a model in which the initial number and type distribution of firms are exogenous. We show that second-period expected quality decreases with the number of firms. The reason is that as the number of firms increases, the information accumulation process on firm type becomes less effective. As the number of brands increases, the average number of observations per product is reduced. Then, the spread of good and bad reputations among firms is based on less information. As a result, a larger fraction of low-quality firms are able to stay in the market for a longer period, thereby lowering average product quality. If the value of quality is large enough with respect to the value of variety, then as the number

[1] For example, according to a 2003 report from the consulting firm McKinsey the number of brands on US grocery store shelves tripled in the 1990s from 15,000 to 45,000. Between 1970 and 1997, the number of vehicle models increased from 140 to 260 and the number brands of bottled water increased from 16 to 50 (Federal Reserve Bank of Dallas 1998). By 2009, the number of vehicles and brands of water were 365 and 128 respectively (www.automotive.com and www.bottledwater.org). In turn, Broda and Weinstein (2006) estimate that imported product varieties in the US increased by a factor of three between 1972 and 2001.

of firms increases, the negative effect of diminishing expected quality can eventually offset the benefits of lower prices and wider diversity.

In the second part of the paper, we extend our model to endogenize the number of firms and distribution of firm types. In equilibrium, a larger global market implies more firms in each local market but fewer incentives to produce good-quality products[2]. In addition to the negative effect that low-quality firms survive longer in a market with more firms, now a larger fraction of firms choose to be bad-quality producers. Under some plausible conditions, we find that there is an optimal market size from a social welfare point of view. Beyond that optimal size, the negative (marginal) expected-quality effect of larger markets outweighs the favorable (marginal) price and wider-variety effects.

It should be clear that the analysis in this paper does not mean that, as a result of the increase in the number of brands and suppliers, average quality and social welfare tend now to be lower than they were previously. Average product quality seems to have experienced a significant increase over the last decades as a result of technological progress. The very stylized model proposed in this paper abstracts from the continuous process of technological improvements. Our point is that the large increase in the number of suppliers is likely to exacerbate asymmetric information problems related to product quality, which in turn may to some extent offset the positive effects of stronger competition and technological progress. Thus, the ultimate message of this paper is that the expansion of markets and the ensuing increase in the number of firms require a parallel development of information mechanisms.

Of course, markets respond with new mechanisms to these increasing information needs. However, it cannot be taken for granted that such mechanisms are always developed rapidly and efficiently, as consumer information has public good characteristics. In recent years, new information mechanisms have grown at an extraordinary pace. Product reviews by magazines, consumer associations, and especially websites have given rise to an information industry that has a measurable impact: see Chevalier and Mayzlin (2003) for the effect on sales of online consumer reviews. Nonetheless, these mechanisms have their own specific

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[2] If information flows more easily within local markets than across them (as with word-of-mouth), then information per brand in each local market (i.e., the number of observations about each brand's quality) may decrease, even if world sales per brand increase.

problems[3]. Moreover, even if the Internet greatly extends word-of-mouth possibilities, direct contact with friends, family, and co-workers still seems to be the primary source of reliable information on product quality[4].

In sum, this paper is a first step in investigating the possible trade-off between the number of firms (or market size) on the one hand and consumer information and average quality on the other. We take consumer information mechanisms as given, with the leading example being word-of-mouth within local markets. We leave for future research questions regarding whether markets provide appropriate incentives for creating new information mechanisms and how efficient these new mechanisms may be in solving the wider information problems raised by the expansion and globalization of markets[5].

Our work is related to the literature on experience goods (Nelson, 1970) and reputation (see Bar-Isaac and Tadelis, 2008, for a survey). The literature on reputation analyzes the incentives to produce (costly) high-quality goods instead of (cheap) low-quality goods when consumers cannot distinguish them before consumption. Here, we are interested in how firm incentives and consumer information depend on the size of the market and the number of competitors. Whereas the pioneering works of Klein and Leffler (1981) and Shapiro (1983) apply their analysis in the context of perfect competition, much of the following literature

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[3] Reviews of product quality in the Internet can be manipulated by sellers, are difficult to interpret (reviewers have to be reviewed themselves), do not have zero cost (that is, reading them can be very time consuming), and have been found to be systematically biased in directions and to degrees that are difficult to assess even using sophisticated statistical tools. For example, Hu et al. (2006) analyze the case of books, DVDs, and videos and find that Internet reviews have bimodal distributions. Apparently, reviews are biased because people are much more prone to write a review when they are very satisfied or very unsatisfied with the product. As they are not random samples, these rating results are very difficult to interpret and may be misleading.

[4] Recent research from Nielsen, a well-known consulting firm on consumer media and marketplace behavior reveals that 90% of consumers consider recommendations from people they know to be trustworthy, much more than information from any other sources; see *Nielsen Global Online Consumer Survey. Trust, Value and Engagement in Advertising* (2009), which is available at http://pl.nielsen.com/trends/documents/Niel-senTrustAdvertisingGlobalReportJuly09.pdf. According to Keller and Berry (2006) from the consulting firm Keller Fay Group, 90% of word-of-mouth conversations still occur face to face, while only 7% occur online. See also Dellarocas (2003) for a survey on the role of new information technologies on word-of-mouth communication.

[5] See Armstrong (2008) for a discussion on problems associated with the so-called *market for market information*.

focuses on the case of a single seller. More recent papers analyze the effect of different degrees of competition in providing incentives for quality reputation; see Hörner (2002), Kranton (2003), Bar-Isaac (2005), Rob and Fishman (2005), Rob and Sekiguchi (2006), Marimon et al. (2009), and Dana and Fong (2010). In these papers, different degrees of competition affect firm incentives for quality through their impact on profit margins and the potential for consumer defection. In this paper, we focus on a different mechanism; namely, the impact of market size and the number of firms on average consumer information, which in turn determines the distribution of product quality in the market. To the extent of our knowledge, this paper is the first to suggest a possible trade-off between product diversity and consumer information.

The paper is also related to the industrial organization literature on information diffusion and word-of-mouth, as has been investigated by Kennedy (1994), Vettas (1997), and Navarro (2008) in the context of monopolies, and by Caminal and Vives (1996 and 1999) in the context of duopolies. Again, this literature has not explored how the precision of consumer information depends on the number of firms in the market.

The rest of the paper is organized as follows. In section 2, we analyze average quality and welfare as a function of the number of firms, taking the number and type distribution of firms in the market as exogenous. We first consider a very simple information diffusion mechanism and carry out the analysis under some further simplifying assumptions. Then, we extend the analysis using a more general, abstract mechanism. In section 3, we endogenize the number and type distribution of firms. In this setting, we explore the consequences of market expansion on average quality and welfare. We summarize and conclude in section 4.

2. Uncertain Quality and the Number of Firms

WE build our model on the circular city model proposed by Salop (1979). There are n firms and A consumers uniformly distributed around a circular city with a perimeter equal to 1. All firms have the same constant marginal cost $c > 0$ and set their prices simultaneously. There are linear transportation costs τx, where x is the distance between the consumer and the firm from which she buys. As is customary, the circle where firms and consumers are located may be interpreted as a space of product characteristics; consumers have different preferences over these characteristics, while firms choose which characteristics to supply. We will also refer to τ as the *value of proximity* between a consumer's location and a firm's location or between a consumer's preferences and product characteristics. Each consumer buys only one unit of the good per period as long as the cost (that is, price plus transportation) does not exceed the good's expected value.

We embed this standard horizontal-differentiation setting into a two-period model and introduce three new features:

1) Goods may be good quality (denoted $q = 1$) or bad quality (i.e., *lemons*, denoted as $q = 0$).
2) Firms may be of high type *(H)* or low type *(L)*. *H*-type firms only produce good quality. In contrast, each unit produced by an *L*-type firm is good quality with probability β , $0 < \beta < 1$, and is a lemon with probability $1 - \beta$.
3) Consumers cannot observe the quality of goods before they consume them, nor can they directly observe firms' types. At the beginning of period 1, they hold the same priors about each firm's type. At the end of the first period, each consumer has one observation about the firm's output that she bought (i.e., she knows whether the firm delivered a good-quality unit or a lemon). Then, consumers update their priors about firm types based on their consumption experience in that period and the experience of other consumers. They then decide which firm to buy from in the second period.

The value of consuming one unit of a good is V if $q = 1$ and zero if $q = 0$. Consumers and firms discount second-period utility and profits using the same factor $\delta > 0$. The fraction of firms that are *H*-type in the first period is ρ , $0 < \rho < 1$. This fraction is exogenous in this section but will become endogenous in section 3. Parameters β and ρ are common knowledge. Note that no firm will charge a price below c in the second period. The following simplifying assumption ensures that consumers would never buy from an *L*-type firm in the second period should they know its type:

Assumption (1) $c > \beta V$

The (per capita) expected discounted consumer surplus is:

$$E[CS] = V \cdot E[q_1] - P_1 - \tau \cdot d_1 + \delta\left(V \cdot E[q_2] - E[P_2] - \tau \cdot E[d_2]\right) \tag{1}$$

where $E[.]$ is the expectation operator, q_t is quality at period t, P_t is price, and d_t is the average distance between a consumer's locations and the location of the firm from which the consumer buys. Every term in this expression depends on the number of firms in the corresponding period, n_t. Average distance is given by:

$$d_t = \frac{1}{4n_t} \tag{2}$$

For reasons that will become clear below, prices in the second period are given by the standard version of Salop's (1979) model. However, in period 1, there may exist different price equilibria, which can be sustained by appropriate out-of-equilibrium beliefs. At any rate, prices have no influence on social welfare in the model in this section. Any increase in price only represents a transfer of wealth from consumers to producers (because all consumers buy one unit of the good as long as the price is low enough, whereas the number of firms does not depend on prices). Moreover, we restrict our analysis to symmetric pooling equilibria.

In each period, expected quality depends on the type composition of firms. Because this composition is given by ρ in the first period and all firms have the same market share, expected quality at period 1 is:

$$E[q_1] = \rho + (1-\rho)\beta \tag{3}$$

Expected quality in the second period depends on how much information is collected by each consumer at the end of period 1 and how this information drives some L-type firms out of the market. Recall that each consumer directly obtains a single observation on one firm's output. Each consumer's experience may then be transmitted to other consumers at the end of period 1 (e.g., by means of an information-diffusion mechanism such as word-of-mouth, magazine and newspaper reviews, Internet ratings, or consumer association bulletins). We consider two different settings in this respect. In subsection 2.1, we assume the simple case in which all consumers share all of their information. Furthermore, we simplify the computation of equilibrium in this subsection by assuming a large number of firms. In subsection 2.2, we generalize the results by considering an abstract information-diffusion and firm-sorting mechanism that is characterized by a general property.

Ignoring at this point the possible existence of fixed costs (they are introduced in section 3), per capita expected social welfare is:

$$E[SW] = V \cdot E[q_1] - \tau \cdot d_1 + \delta\left(V \cdot E[q_2] - \tau \cdot E[d_2]\right) - (1+\delta)\ \ c \qquad (4)$$

As is well known, asymmetric information on product quality may create difficulties for the existence of markets (Akerlof 1970). In addition, transportation costs may be so high as to dissuade some consumers from buying goods. We consider economies such that in equilibrium all consumers buy one unit of the good at each period. This is ensured by the following assumption.

Assumption (2) $V \cdot [\rho + (1-\rho)\beta] \geq \frac{3}{2n_1}\tau + c$

This assumption guarantees that for the consumer who is farthest away from her closest firm, expected utility in the first period is at least as large as the good's price plus transportation cost[6]. In what follows, we omit the subindex 1 when denoting the initial number of firms in order to simplify the notation (i.e., $n \equiv n_1$).

2.1. A simple information-diffusion mechanism

In this subsection, we assume that each consumer's information about the quality of the good she consumed in period 1 is transmitted to the entire population before anyone decides which firm to buy from in the second period. Hence, consumption in the first period produces a sample of size $m = A/n$ of each firm's output, where m is also sales per firm.

[6] It can be shown that if assumption (2) holds, then all consumers are willing to buy in the second period as well.

This sample is available to all consumers[7]. Because *H*-type firms only produce good quality, Bayesian updating implies that firms that produce one or more bad-quality units reveal to be *L*-type to all consumers at the end of period 1. As a result of this and assumption (1), these firms abandon the market. Remaining firms relocate uniformly around the city circle at the beginning of the second period.

Let *B* be the fraction of *L*-type firms surviving into the second period. This is a random variable with mean $\beta^{A/n}$, which is the probability that an *L*-type firm produces *A/n* high-quality units in a row. We simplify computations by substituting $\beta^{A/n}$ for *B*. This substitution can be justified assuming that *n* is large enough so that the *Law of Large Numbers* implies that $B \approx \beta^{A/n}$. In the next subsection, we solve the model taking into account the whole distribution of *B* and show that the same results hold. Thus, using $\beta^{A/n}$ to substitute for *B*, the number of surviving firms in the second period is:

$$n_2 = \left[\rho + (1-\rho)\beta^{\frac{A}{n}} \right] \; n \tag{5}$$

Note that n_2 / n (that is, the proportion of firms surviving into the second period) is increasing in *n*; in fact, $\lim_{n\to\infty} n_2 = n$. Thus, the fraction of *L*-type firms that are disclosed decreases with *n*. As a result, expected quality of aggregate output in the second period, $E(q_2)$, is also decreasing in *n*:

$$E[q_2] = \frac{\rho + (1-\rho)\beta^{\frac{A}{n}+1}}{\rho + (1-\rho)\beta^{\frac{A}{n}}} \tag{6}$$

Expected per capita social welfare is then easily obtained using expressions (2), (3) and (6) to substitute in (4):

$$E[SW] = V \cdot Q - \tau \cdot D - (1+\delta)c \tag{7}$$

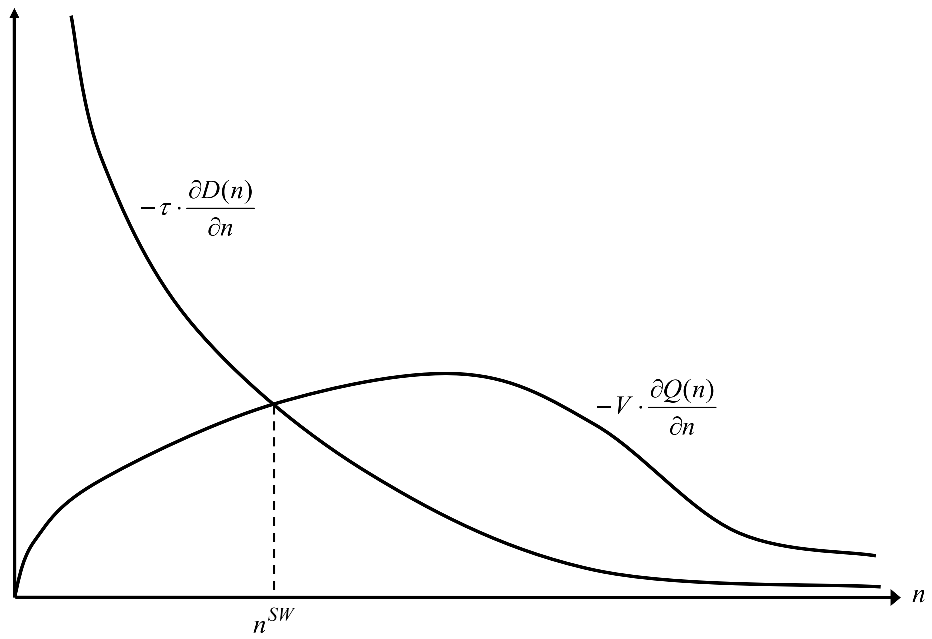
[7] As in Salop's (1979) original model, the total population *A* is treated as a continuum and, presumably, a *large* number. Notwithstanding, the ratio *A/n* may be small as long as *n* is also large.

where

$$Q = \rho + (1-\rho)\beta + \delta \frac{\rho + (1-\rho)\beta^{\frac{A}{n}+1}}{\rho + (1-\rho)\beta^{\frac{A}{n}}}, \quad D = \frac{1}{4n}\left[1 + \frac{\delta}{\rho + (1-\rho)\beta^{\frac{A}{n}}}\right] \tag{8}$$

The first term in expression (7) is the expected discounted value of consumption. The second term is the expected discounted cost of distance. An increase in the number of firms has two opposing effects on $E[SW]$. On the positive side, it reduces the average distance between firm and consumer location (or between product characteristics and consumer preferences). This effect is the *marginal distance* or *variety effect*: $-\tau \cdot \frac{\partial D(n)}{\partial n} > 0$. On the negative side, an increase in the number of firms raises the fraction of *L*-type firms that stay in the market in the second period, thereby lowering expected quality in that period. This is the *marginal information or expected-quality effect*: $V \cdot \frac{\partial Q(n)}{\partial n} < 0$. See figure 1, which shows $-V \cdot \frac{\partial Q(n)}{\partial n}$ and $-\tau \cdot \frac{\partial D(n)}{\partial n}$.

FIGURE 1: Asymmetric information and the optimal number of firms



Note: Marginal information and marginal distance effects as a function of the number of firms *n*. Their crossing determines the number of firms n^{SW} that maximizes social welfare.

The marginal distance effect tends to infinity as the number of firms approaches zero and decreases monotonically as the number of firms increases because having additional brands available is decreasingly valuable to consumers. However, the relationship between the marginal information effect and the number of firms is not monotonic. If consumers have as much information as they need, then an additional piece of information is worthless. This is what tends to happen if the number of firms is very small; in this case, consumers can identify all low-quality firms at the end of the first period with almost certainty. Hence, the marginal information effect tends to zero as the number of firms approaches zero. However, as the number of firms increases, consumer information becomes less precise so that additional pieces of information become more valuable. Thus, the marginal information effect rises, at least for some interval of n. Whether this marginal information effect may at some point become larger than the marginal distance effect depends on consumer valuation for quality, V, with respect to consumer valuation for proximity, τ. The smaller that τ is, the less important the marginal distance effect is. Conversely, the larger that V is, the more important the negative marginal information effect is. If the ratio V/τ is sufficiently large, then there exists a number of firms $n^{SW} > 0$ such that the two schedules cross each other; that is, for $n = n^{SW}$ we have $-V \cdot \frac{\partial Q(n)}{\partial n} = -\tau \cdot \frac{\partial D(n)}{\partial n}$ (see figure 1). Thus, social welfare is maximized at this point. Furthermore, n^{SW} decreases with the importance of quality with respect to proximity (or diversity). Graphically, an increase in the value of quality V shifts the $-V \cdot \frac{\partial Q}{\partial n}$ curve upwards, whereas a reduction in τ shifts the $-\tau \cdot \frac{\partial D}{\partial n}$ curve downwards[8]. Results are summarized as follows[9]:

[8] There may be more than one crossing between the curves. At local maxima we have $V \cdot \frac{\partial^2 Q}{\partial n^2} < \tau \cdot \frac{\partial^2 D}{\partial n^2}$; that is $-V \cdot \frac{\partial Q}{\partial n}$ crosses $-\tau \cdot \frac{\partial D}{\partial n}$ from below. n^{SW} would correspond to the maximum of the set of local maxima. This second order condition guarantees the comparative-statics results.

[9] Salop (1979) also finds that the number of firms may be excessive from the social welfare point of view. However, his result crucially depends on the existence of strictly positive fixed costs: if there are no fixed costs, then social welfare is always increasing with the number of firms. In the present model, results do not depend on firms having positive fixed costs. More importantly, the mechanism is very different from that in Salop's (1979) model. The mechanism here is linked to increasing information problems regarding product quality, whereas in Salop's (1979) model there is complete infor-

Proposition (1): If the value of consuming good quality is large enough with respect to the value of proximity (as measured by the ratio V/τ), then expected social welfare is maximized for a finite (initial) number of firms n^{SW}. Beyond n^{SW}, the positive (marginal) distance effect produced by a large number of firms is outweighed by the negative (marginal) expected-quality effect. Moreover, n^{SW} decreases with the value of quality V and increases with the value of proximity τ.

Proof. See appendix A in section 5.

We can perform a similar analysis in terms of consumer surplus. As noted before, we restrict our analysis to pooling equilibria and consider Salop's (1979) equilibrium price in the first period[10]. The reason for considering Salop's (1979) prices is that they constitute a simple benchmark that has the appealing property that prices monotonically converge to marginal costs as the number of firms tends to infinity. The standard Bertrand equilibrium in Salop's (1979) model yields:

$$P_t = \frac{\tau}{n_t} + c \tag{9}$$

Using equation (9) for prices, the expression for expected discounted consumer surplus is very similar to (7):

$$E[CS] = V \cdot Q - \tau \cdot PD \tag{10}$$

mation and a single product quality. Finally, note also that consumer surplus is always increasing in the number of firms in Salop's (1979) model, which is not the case in this model (see proposition [2]).

[10] Salop's (1979) prices can be sustained in the first period by out-of-equilibrium beliefs that interpret deviations to a lower price as a signal of an *L*-type firm. Another potentially interesting (though somewhat more complex) equilibrium arises if consumers draw no strategic inference whatsoever about a firm's type from its mere decision to deviate. Because deviating to a lower price in the first period would increase sales, *H*-type firms may have incentives to decrease the price in order to generate a larger sample, and thus, more information about their product. This decrease in price would increase the willingness of consumers to pay for the firm's output in the second period. We consider these out-of-equilibrium beliefs and analyze the resulting equilibrium in appendix B in section 6. We show that the first-period prices in this equilibrium are lower than Salop's (1979) prices. However, the same qualitative results (i.e., proposition [2]) hold under this assumption.

where $PD \equiv D + [P_1 + \delta P_2]/\tau$. Note that $\tau \cdot PD = \tau \cdot D + P_1 + \delta P_2 = \tau \cdot 5D + (1+\delta)c$. Therefore, the combined *marginal price and distance effect* of increasing *n* is $-\tau \cdot \frac{\partial PD(n)}{\partial n} = -5\tau \cdot \frac{\partial D(n)}{\partial n}$. It is then easy to see that the same results for social welfare in proposition (1) hold for consumer surplus, except that the condition that V/τ must be sufficiently large has to be reinforced. Because the price and marginal distance effect is five times larger than the marginal distance effect, V/τ now must be larger than in proposition (1).

Proposition (2): If the ratio V/τ is large enough, then expected consumer surplus is maximized for a finite (initial) number of firms n^{CS}. Beyond n^{CS}, the positive (marginal) price and distance effect produced by a larger number of firms is outweighed by the negative (marginal) expected-quality effect. Moreover, n^{CS} is decreasing in V and increasing in τ.

2.2. A general mechanism

We now generalize the results by considering an abstract firm-sorting mechanism that is characterized by a simple property. Recall that *B* is the fraction of *L*-type firms existing in the first period that survive into the second period. The *firm-sorting mechanism* specifies the probability distribution of *B*, which has support $[0,\ 1]$, as a function of the parameters of the economy in the first period. Specifically, let $\phi(B,\ n)$ be the cumulative distribution function of *B*, which depends on the number of firms in the first period. The expected number of firms and quality in the second period respectively are:

$$E[n_2] = n\int_0^1 [\rho + (1-\rho)\ B]\ d\phi(B,\ n) \tag{11}$$

$$E[q_2] = \int_0^1 \frac{\rho + (1-\rho)\ B \cdot \beta}{\rho + (1-\rho)\ B} d\phi(B,\ n) \tag{12}$$

Then, expected social welfare is still given by expression (7), though Q and D are now given by:

$$Q = \rho + (1-\rho)\beta + \delta\int_0^1 \frac{\rho + (1-\rho)\ \ B\cdot\beta}{\rho + (1-\rho)\ \ B} d\phi(B,\ n),$$
$$D = \frac{1}{4n}\left[1 + \delta\int_0^1 \frac{1}{\rho + (1-\rho)\ \ B} d\phi(B,\ n)\right] \tag{13}$$

Differentiating (7) with respect to n and taking (13) into account, we can explore the existence of a maximizer. The existence depends on the characteristics of $\phi(B,\ n)$. We postulate that given the rest of parameters in the economy (such as A, ρ, and β), the larger that n is, the higher the probability is that low-type firms survive into the second period. The reason is that given the total consumption of the good, a larger number of firms in the market implies fewer observations of each firm's output. This is true regardless of which information diffusion mechanisms are present in the economy. Therefore, larger n implies less chances per period that consumers recognize low-type firms and stop buying from them. In other words, larger n leads to distributions of B that first-order stochastically dominate the distributions resulting from lower n. Moreover, we also postulate that as the number of observations per firm tends to infinity ($n \to 0$), all L-type firms are disclosed and driven out of the market at the end of the first period. Formally, we have the following assumption.

Assumption (3) $\lim_{n\to 0}\phi(B \le 0, n) = 1$ and $\partial\phi(B,n)/\partial n < 0$ for all $B \in (0,1)$

Under this assumption, the analysis is analogous to that in the previous subsection. Figure 1 is again valid to represent $-V\cdot\frac{\partial Q(n)}{\partial n}$ and. For small n, the positive *marginal distance effect* on social welfare, $\tau\cdot\frac{\partial D(n)}{\partial n}$, dominates the negative *marginal information/quality effect*, $V\cdot\frac{\partial Q(n)}{\partial n}$. However, if the value of quality V is large enough with respect to the value of proximity τ as the number of firms grows, the marginal information/quality effect eventually dominates the marginal distance effect. Thus, proposition (1) is generalized as follows[11]:

> ***Proposition (3)**:* Consider an economy in which L-type firms are driven out of the market according to a firm-sorting mechanism that satisfies assumption (3). If V/τ is sufficiently large, then expected social welfare is maximized for a finite (initial) number of firms n^{SW}. Moreover, n^{SW} is decreasing in V and increasing in τ.
>
> **Proof**. See appendix A in section 5.

If consumer information is based on consumption experiences across the set of consumers, then most information diffusion mechanisms (such as word-of-mouth, registry of consumer complaints, and Internet reviews) would likely lead to a sorting of firms as characterized by assumption (3). Given the rest of the parameters in the economy, such as the number of consumers, larger n implies fewer observations of each firm's output. The fewer observations per unit of time there are on each firm's output, the less likely it is that low-quality firms are rapidly disclosed and driven out of the market. If this general principle stands, then the main message of the paper (namely, that larger markets may reduce welfare in some industries due to information problems) is likely to follow independently of the details of the information diffusion mechanism.

3. Entry and Quality in Expanding Markets

IN this section, we endogenize the initial number n of firms and the initial distribution of their types ρ as a function of market size. We then explore the relationship between market size, and average quality and welfare.

[11] Proposition (2) can also be generalized following a very similar argument.

There is free entry to the market subject to fixed costs. Firms can choose to be *H*-type, in which case they pay entry costs K_H, or *L*-type, in which case they pay K_L; $K_H > K_L > 0$. In all other respects, the technology is the same as before. Marginal costs c are the same for both firm types, and each unit that is produced by an *L*-type firm will turn out to be a lemon with probability $1-\beta$, whereas *H*-type firms never produce lemons. Thus, we now have a three-stage model. At time 0, firms choose whether or not to enter the market and which type of firm to be. Then, periods 1 and 2 evolve as described above.

We carry out the analysis using the simple setting considered in subsection 2.1, though instead of a single city we now consider a *global market* comprised by *z* identical circular *cities* (local markets or countries). Each city has A consumers who are uniformly distributed around the circle. The size of the (global) market is denoted by *S*; $S \equiv z \cdot A$. We analyze the consequences of market expansions consisting of increases in *z*, with A remaining constant. Thus, market expansion means that firms are able to sell in more cities[12]. This market expansion will lead to a new equilibrium in which consumers in each city are able to buy from more firms.

All cities are served by all firms in the first period. At the end of the first period, consumers within each city share their information on firm types. However, information does not flow across cities; that is, consumers from one city do not communicate with consumers in another city[13]. As a consequence, in the second period, *L*-type firms stop

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[12] This would be the result of factors such as reductions in transport costs, new information and communications technologies facilitating firm operations in more remote areas, or increases in openness to international trade.

[13] This assumption is motivated by the fact that not all consumption experiences are transmitted to all consumers as the number of local (and national) markets that are served by a given firm increases. For example, word-of-mouth across different local and national markets is much weaker than within a given local market, consumer magazines and associations tend to have a limited spatial coverage, and product reviews in the Internet are written in different languages that are specific to different countries, whereas the same firms may be selling in many of these local and national markets. This setting can also be interpreted in other ways. Formally, the simplifying assumption in the model is that there is a partition over the set of consumers such that each subset shares information on past consumption experiences. An alternative interpretation of

selling in those cities where they sold one or more lemons in the first period, whereas all H-type firms continue selling in all cities. Note that both types of firms obtain the same profits in the first period because there is still no specific information on individual firms and we restrict the analysis to pooling equilibria. However, H-type firms obtain higher expected profits in the second period, which compensates for their higher fixed costs. Depending on the size of K_H relative to K_L and the time discount, equilibria in which both types of firms are active may not exist or exist only for a given range of market sizes. We introduce sufficient conditions that guarantee that both types of firms are active in equilibrium for a non-empty interval of market sizes. Outside that interval there is no uncertainty regarding product quality and therefore there is no trade-off between variety and information.

As in subsection 2.1, we simplify the analysis by assuming that the fraction of L-type firms that remain undisclosed in each city after the first period is equal to the expected value of this fraction. That is, a fraction $\beta^{A/n}$ of L-type firms remains undisclosed in each city after the first period, though not necessarily the same firms remain undisclosed in all cities. Firms are risk neutral. Hence, potential L-type entrant firms compute expected profits knowing that their probability of being undisclosed in a given city after the first period is $\beta^{A/n}$ or, equivalently, knowing that the expected fraction of cities in which they will continue selling in the second period is $\beta^{A/n}$.

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this setting might be the following. There is a single city in which the set of consumers is partitioned into z groups of friends. Each group of friends has A individuals. As the city grows, the number of friend groups increases, while the size A of each group remains constant. Each individual shares information about her consumption experience in the previous period with all of the friends in her group, but she shares no information with individuals in other groups of friends.

3.1. Equilibrium with endogenous entry and firm types

Normalize $K_H = 1$. Using expression (9) for prices yields per firm gross profits in period t, $\pi_t = S\tau \frac{1}{n_t^2}$. Then, free entry to the market as an H- and as an L-type firm respectively yields:

$$S\tau\left(\frac{1}{n^2}+\frac{\delta}{n^2\left[\rho+(1-\rho)\beta^{\frac{A}{n}}\right]^2}\right)-1\leq 0 \tag{14}$$

$$S\tau\left(\frac{1}{n^2}+\frac{\delta\beta^{\frac{A}{n}}}{n^2\left[\rho+(1-\rho)\beta^{\frac{A}{n}}\right]^2}\right)-K_L\leq 0 \tag{15}$$

Assumption (1) implies that for an equilibrium with positive production to exist, some H-type firms must be active. Therefore, (14) must always be satisfied with equality. However, there may or may not be active L-type firms in equilibrium. If they are active, then (15) is also satisfied with equality such that expressions (14) and (15) respectively yield:

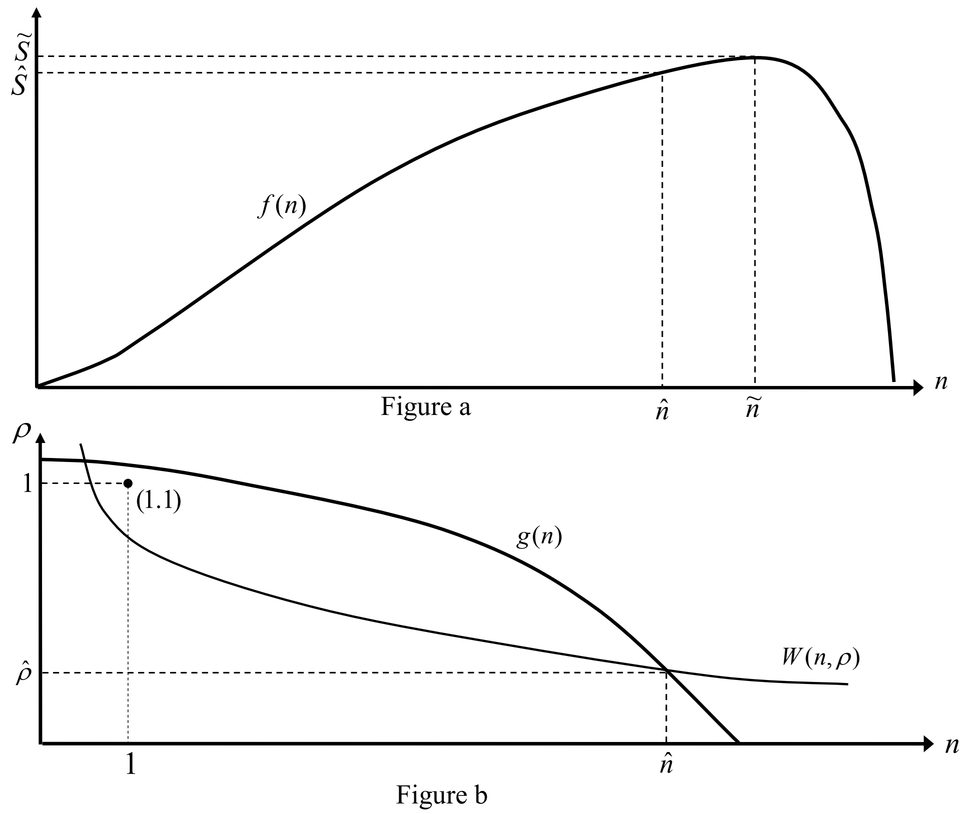
$$S=\frac{n^2}{\tau}\frac{K_L-\beta^{\frac{A}{n}}}{1-\beta^{\frac{A}{n}}}\equiv f(n) \tag{16}$$

$$\frac{K_L-\beta^{\frac{A}{n}}}{\left[\rho+(1-\rho)\beta^{\frac{A}{n}}\right]^2}=\frac{1-K_L}{\delta} \tag{17}$$

These two expressions determine n and ρ as long as $0<\rho<1$ and all consumers are willing to buy one unit of the good.

Let us first consider expression (16), which defines a continuous mapping between the number of firms and market size $S = f(n)$. This mapping is initially increasing and then decreasing, so that it can have at most one maximum, and it satisfies $f(0)=0$ [14]. Denote the maximum of $f(n)$ by $\tilde{S}$, which is attained at $\tilde{n}$ (see figure 2.a).

FIGURE 2: Market size, the number of firms and the share of high-type firms



Note: The mappings *f (n)* and *g(n)* represent the equilibrium conditions for the initial number of firms *n* and the initial share of high-type firms ρ, if both high- and low-type firms are active and all consumers buy one variety of the good. In turn, all consumers would be willing to buy one variety of the good if the pair (*n*, ρ) is above *W* (*n*, ρ), so that expected quality is high enough and distances between varieties and consumer preferences are low enough.

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14 Note that $df/dn = H(x)\cdot n/\tau(1-x)^2$, where $H(x)\equiv 2(K_L - x)(1-x)+(1-K_L)x\ln x$ and $x \equiv \beta^{\frac{A}{n}}$, which is strictly increasing in n for $n\geq 0$. Note that $dH/dx = x-1+3(x-K_L)+(1-K_L)\ln x<0$, where the last inequality is a consequence of $K_L<1$, $x<1$, and $x<K_L$ (see equation [16]). Hence, $H(x)$ must be always positive, first positive and then negative, or always negative; and so must be df/dn because the term $n/\tau(1-x)^2$ is strictly positive. Therefore, $f(n)$ can have at most one maximum.

Now, consider expression (17). We can use it to define a mapping $\rho = g(n)$. Note that $\partial g(n)/\partial n < 0$ (see figure 2.b). The negative relationship between n and ρ can be explained as follows. When firms choose their type, they face a trade-off between entry costs and expected second-period profits. Choosing to be L-type e involves a lower entry cost K_L, whereas choosing to be an H-type firm yields higher expected profits in the second period (when only H-type firms continue selling in all local markets or to all consumer groups). A large n increases the relative profits of L-type firms with respect to H-type firms because it reduces the chances that an L-type firm is disclosed (recall that consumers gather less information per firm at the end of the first period). This relative advantage for L-type firms can be compensated by lower ρ, because then a larger fraction of the total number of firms abandon the market after the first period, leaving higher prices and profits to the remaining firms. This increases the discounted profits of H-type firms relative to L-type firms. Hence, a large n requires a low ρ in order that both types of firms have the same expected discounted profits.

As already noted in the discussion of assumption (2), consumers may not buy any good if the expected quality is too low or the distance to the nearest firm is too large (i.e., if either ρ or n are too small). Denote by $W(n,\rho)$ the frontier of the (n,ρ) pairs such that all consumers want to buy a unit of the good in the first period[15] (see figure 2.b). Only points in the segment of $g(n)$ above $W(n,\rho)$ are potential equilibria in which all consumers would buy one variety of the good. The following two assumptions are sufficient conditions to guarantee that this segment is non-empty.

Assumption (4) $V \geq \frac{3}{2}\tau + c$

Assumption (5) $K_L \geq \frac{1+\delta \ \beta^A}{1+\delta}$

[15] $W(n,\ \rho) \equiv \{(n,\ \rho) \in R_+^2 : V \cdot \left[\rho + (1-\rho)\beta\right] = \frac{3}{2n}\tau + c\}$. It is easy to see that $W(n,\ \rho)$ is decreasing and convex, and has $\lim_{n\to\infty} \rho(n) = \frac{c/V-\beta}{1-\beta} > 0$.

Assumption (4) above substitutes for assumption (2), which was only appropriate for exogenous ρ and n. It implies that V is large enough so that if there were only a single H-type firm, then all consumers would buy its output. In turn, assumption (5) implies that if the market is so small that there is only room for a single firm, then in equilibrium this single firm would be of H-type. That is, for $n=1$ we would have $\rho=1$ [16]. Moreover, assumption (5) implies that the point (1,1) lies on or below $g(n)$, whereas assumption (4) implies that (1,1) lies on or above $W(n,\rho)$. Therefore, $g(n)$ and $W(n,\rho)$ cross twice, leaving the point (1,1) in between. Denote by $(\hat{n},\hat{\rho})$ the second crossing; see figure 2.b. Note that we always have $\hat{\rho}>0$.

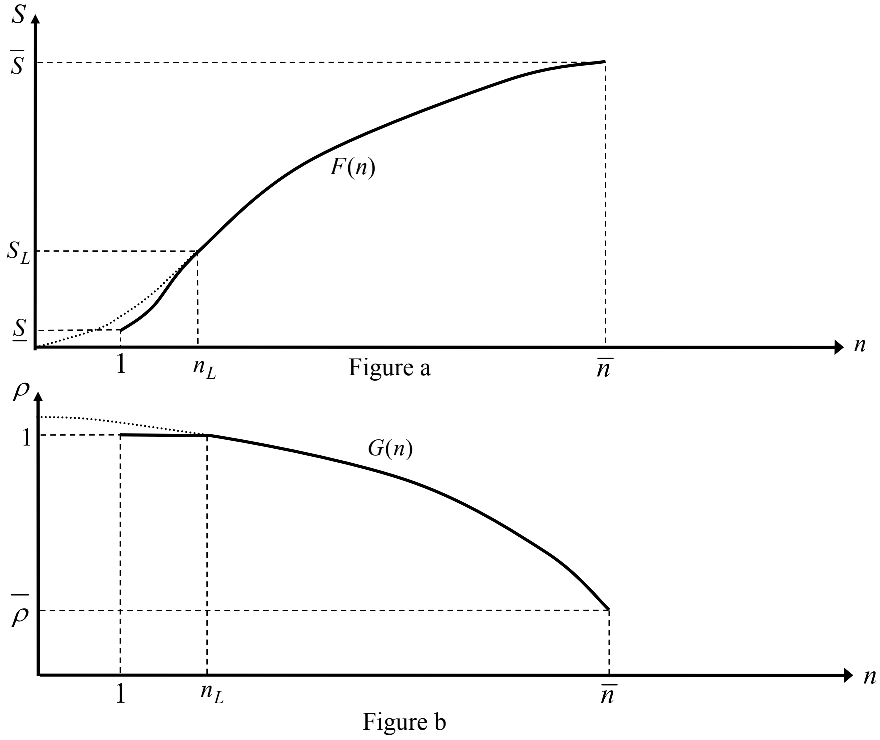
Now recall, that (16) and (17) determine n and ρ as long as $0<\rho<1$. However, if there are no active L-type firms (i.e., $\rho=1$), then the number of firms is given by:

$$S=\frac{1}{(1+\delta)\ \tau}n^2 \tag{18}$$

Because $g(n)$ goes above the point $(1,\ 1)$, we necessarily have $\rho=1$ for a segment $n\in(0,\ n_L]$, where $n_L>1$ (see figure 3.b). The reason why there are only H-type firms when n is small is intuitive. If there are few firms, then consumers rapidly accumulate a large amount of information per firm. As a result, they quickly discover L-type firms and stop buying from them. In our model, this means that L-type firms have a low probability of surviving at the end of the first period. This in turn prevents L-type firms from entering the market in the first period altogether.

[16] To see this substitute in (17) with $n=1$ and $K_L=\frac{1+\delta\ \ \beta^A}{1+\delta}$. The intuition is that if the number of firms is small (as is the case with $n=1$), then consumers obtain a large amount of information about each firm's type at the end of period 1. Therefore, the probability that an L-type firm survives at the end of this period is very low. This prevents L-type firms from entering the market in the first period altogether if K_L is sufficiently high.

FIGURE 3: Market size, the number of firms and the share of high-type firms



Note: For any market size $S \in [\underline{S}, \overline{S}]$, the inverse mapping $n = F^{-1}(S)$ determines the initial number of firms n. In turn, $G(n)$ determines the initial share of H–type firms, ρ, as a function of n.

Formally, for $n \in (0,\ n_L]$, the equilibrium relationship between n and S is not given by (16) but by (18), whereas the equilibrium relationship between n and ρ is not given by (17) but by $\rho = 1$. Also, note from (18) that the market size leading to a single active firm is $S = 1/(1+\delta)\tau$. For $S < 1/(1+\delta)\tau$, the market is too small for any firm to cover its fixed costs, and therefore no firm would produce the good. We need some additional notation to take these points into account. Denote $\underline{S} \equiv 1/(1+\delta)\tau$, $\overline{n} \equiv \min\{\hat{n}, \tilde{n}\}$, $\overline{S} \equiv f(\overline{n})$, and $\overline{\rho} \equiv g(\overline{n})$ [17]. Furthermore, define the mappings $F(n): [1,\ \overline{n}] \rightarrow [\underline{S},\ \overline{S}]$ and $G(n): [1,\ \overline{n}] \rightarrow [\overline{\rho},\ 1]$ as:

[17] In figure 2 we represent the case in which $\tilde{n} \geq \hat{n}$. It may also be the case that $\tilde{n} < \hat{n}$. Note that if

$$S = F(n) \equiv \begin{cases} \frac{1}{(1+\delta)\,\tau} n^2 & \text{for} \quad n \in [1,\ n_L]; \\ f(n) & \text{for} \quad n \in (n_L,\ \overline{n}]. \end{cases} \tag{19}$$

$$\rho = G(n) \equiv \begin{cases} 1 & \text{for} \quad n \in [1,\ n_L]; \\ g(n) & \text{for} \quad n \in (n_L,\ \overline{n}]. \end{cases} \tag{20}$$

See figures 3.a and 3.b (the dotted lines correspond to the portions of $f(n)$ and $g(n)$ that are not equal to $F(n)$ and $G(n)$, respectively). For any market size $S \in [\underline{S},\ \overline{S}]$, the inverse of $F(n)$ determines the initial number of firms *n*. Then, given *n*, $G(n)$ determines the initial fraction ρ of *H*-type firms. For small market sizes (specifically, when $S < S_L$), consumers have plenty of information about the few existing firms. This makes it unprofitable to start an *L*-type firm. As the market increases in size (i.e., for $S > S_L$), the share of *L*-type firms is positive and increasing. We thus have the following result:

> ***Proposition (4):*** Let assumptions (4) and (5) hold. There exists a range of market sizes $[\underline{S},\ \overline{S}]$, $0 < \underline{S} < \overline{S}$, such that for each $S \in [\underline{S},\ \overline{S}]$ there is an equilibrium in which there is positive production and each consumer buys one unit of the good. Moreover, in small markets (specifically if $S \in [\underline{S},\ S_L]$, $\underline{S} < S_L < \overline{S}$), all firms are *H*-type, whereas in larger markets (i.e., if $S \in (S_L,\ \overline{S}]$), there are active firms of both types.

$\tilde{n} < \hat{n}$, there would be two equilibrium candidates for market sizes close to $\overline{S}$; i.e., for some $S < \overline{S}$, but close to $\overline{S}$, there would be two pairs (n, ρ) satisfying equations (16) and (17) and the constraint defined by $W(n, \rho)$. Each of these two candidates would be on a different side of $\tilde{n}$. However, a simple dynamic argument suggests that only the equilibrium candidate on the increasing side of $f(n)$ (i.e., with $n \leq \tilde{n}$) would be stable. To see this, consider an equilibrium pair (n^*, S^*) and then assume that *S* increases. If nothing else changes, then both types of firms would obtain strictly positive profits. Therefore, we should expect entry, i.e., an increase in *n*. Moreover, as the number of firms increases, *L*-type firms obtain relatively more profits than *H*-type firms, implying a decrease in ρ, as given by $g(n)$. However, an equilibrium to the right of $\tilde{n}$ would imply the opposite. Hence, we restrict our attention to the increasing side of $f(n)$.

3.2. Comparative statics: expanding markets

The following result is an almost immediate implication of the previous proposition and summarizes the effects of expanding markets on average product quality.

Proposition (5): Let assumptions (4) and (5) hold and consider market sizes in the interval $[\underline{S},\ \overline{S}]$. As the market expands, the number of firms increases, which implies lower prices and a wider variety of goods. On the negative side, for $S \in (S_L,\ \overline{S})$, $\underline{S} < S_L < \overline{S}$, average product quality (in both periods) decreases as the market expands. This is the consequence of the fact that the initial share and the survival rate of L-type firms increases with market size.

Proof. See appendix A in section 5.

Intuitively, if consumer information is linked to past experiences of consumption, then a large number of firms slows down consumer accumulation of information per firm, thereby facilitating L-type firms to continue selling after the first period, as argued in section 2. This negative effect on expected quality is reinforced if firms choose their type; as markets become large and consumers have less information on each firm, an increasing fraction of firms choose to be L-type .

3.3. Welfare

Can the reduction in expected quality resulting from larger markets outweigh the social welfare benefits of lower prices and wider consumption variety? We now explore this question. We only refer to social welfare because profits are now zero and therefore consumer surplus is identical to social welfare. As before, we focus on equilibria such that all consumers buy one unit of the good. Thus, we consider $S \in [\underline{S},\ \overline{S}]$.

Expected discounted social welfare is now:

$$E\left[SW\right] = V \cdot Q\left(n,\ \rho\right) - \tau \cdot PD\left(n,\ \rho\right) \tag{21}$$

where, as in section 2, $PD = 5D + (1+\delta)\ \ c/\tau$, and Q and D are given by (8). However, note that in this context n and ρ are endogenous variables that depend on market size. Differentiating (21) with respect to S yields:

$$\frac{dE[SW]}{dS} = V \cdot MIE(S) - \tau \cdot MPDE(S) \tag{22}$$

where

$$MIE(S) \equiv \left[\frac{\partial Q}{\partial n} + \frac{\partial Q}{\partial \rho}\frac{\partial \rho^*}{\partial n}\right]\ \frac{\partial n^*}{\partial S},\quad MPDE(S) \equiv \left[\frac{\partial PD}{\partial n} + \frac{\partial PD}{\partial \rho}\frac{\partial \rho^*}{\partial n}\right]\ \frac{\partial n^*}{\partial S}$$

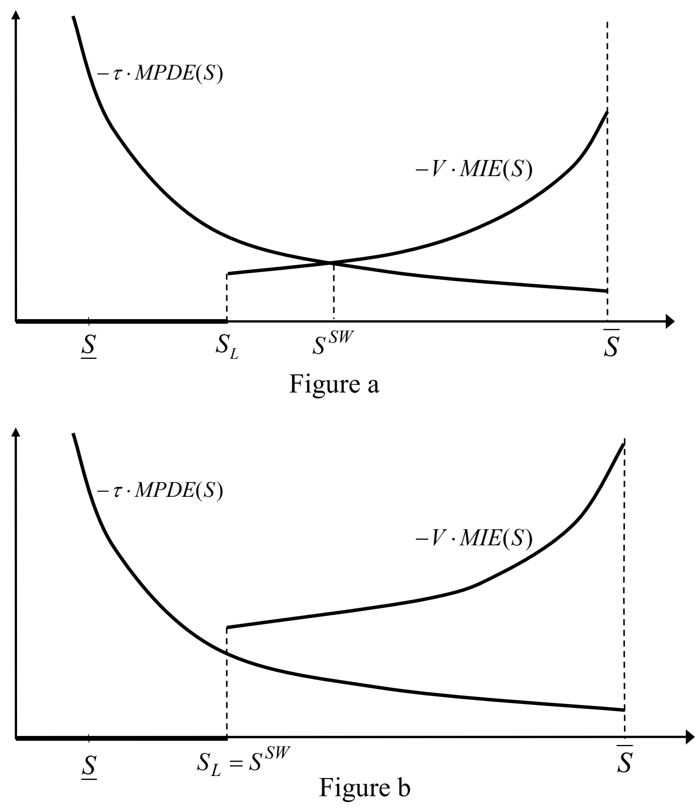
MIE stands for *marginal information effect* (per unit of *V*) with respect to increasing market size, whereas *MPDE* stands for *marginal price and distance effect* (per unit of τ). These effects are functions of market size, as drawn in figures 4.a and 4.b.

The arguments regarding the existence of a market size S^* that maximizes social welfare are similar to those in the previous section. Consider first *MPDE*. As market size and the number of firms increase, the additional benefits of price reductions and higher proximity are monotonically decreasing; i.e., the absolute value of *MPDE* is decreasing for all the relevant range $[\underline{S},\ \overline{S}]$ of market size. In contrast, *MIE* is not monotonic. If the market is small (i.e., for $S \in [\underline{S},\ S_L]$) all firms are *H*-type. Therefore, as market size increases within $(\underline{S},\ S_L)$, there is no reduction in consumer information and expected quality. Thus, welfare is increasing within this interval. However, when the market becomes large enough (specifically, for $S > S_L$), consumer information per firm deteriorates and we have $\rho < 1$. This reduces expected quality and makes additional information on firm type to become more valuable. Thus, *MIE* jumps from 0 to strictly positive (in absolute value) at S_L. Hence, *MIE* starts going in the opposite direction that *MPDE*.

Is there an optimal market size S^{SW}? If the quality value V is very small relative to the value of proximity, then $-V \cdot MIE$ and $-\tau \cdot MPDE$ may never cross each other.

That is, $-V \cdot MIE$ may lie below $-\tau \cdot MPDE$ for the entire interval $[\underline{S},\ \overline{S}]$. Hence, social welfare always increases with market size. However, if V is sufficiently large or τ is sufficiently small, then there is an optimal market size from the point of view of social welfare. There are two possible cases as illustrated in figures 4.a and 4.b. In the first case, $-V \cdot MIE$ and $-\tau \cdot MPDE$ cross each other at S^{SW} such that $S_L < S^{SW} < \overline{S}$ (note that $-V \cdot MIE$ approaches from below, satisfying the second order conditions of a maximum). In the second case, which occurs for very large values of V (figure 4.b), $-V \cdot MIE$ is above $-\tau \cdot MPDE$ at $S = S_L$. Therefore, S_L is the market size that maximizes social welfare.

FIGURE 4: Asymmetric information and the optimal size of the market



Note: Marginal information effect (*MIE*) and marginal price-and-distance effect (*MPDE*) as a function of market size *S*. The figures show the two possible cases for the size S^{SW} that maximizes social welfare.

Finally, note that the $-V \cdot MIE(S)$ curve shifts upward as V increases, whereas the $-\tau \cdot MPDE(S)$ curve shifts downward when τ decreases, thereby reducing S^{SW} if $S^{SW} > S_L$. The following proposition summarizes these findings.

Proposition (6): Let assumptions (4) and (5) hold and consider market sizes such that in equilibrium, each consumer buys one variety of the good (i.e., $S \in [\underline{S},\ \overline{S}]$). If the value of consuming good quality is large enough with respect to the value of proximity (i.e., for V/τ sufficiently large), then there exists a market size S^{SW}, $S^{SW} \in [S_L,\ \overline{S})$, that maximizes expected social welfare. For $S > S^{SW}$, the positive (marginal) price and distance effects produced by a large market are outweighed by the negative (marginal) expected-quality effect. Moreover, if $S^{SW} > S_L$, then S^{SW} strictly decreases with V and increases with τ.

Proof. See appendix A in section 5.

4. Concluding Comments

THE number of brands, models, and sellers available to consumers has soared over the last decades. If consumer information about each product's quality is linked to the quantity that was consumed in the past by a given group of individuals, then a larger number of varieties may imply less information on average about the quality of each variety. This circumstance may in turn decrease incentives among firms to produce high-quality goods. Benefits from lower prices and wider diversity that tend to go along with a larger number of firms may compensate for lower average quality, but this is not necessarily the case. We have shown that beyond some point, social welfare may decrease as a result of the increase in the number of firms and the resulting decrease in consumer information on each firm.

It has long been recognized that under asymmetric information, markets may be inefficient. This paper shows that asymmetric information problems may increase with the size of the market. For instance, standard information mechanisms such as word-of-mouth may work well in relatively small markets but may not work so effectively if markets grow large. This may be important in the era of global markets.

Thus, the bottom line of this paper is that information mechanisms need to be improved as globalization progresses and product supply widens. Otherwise, lower prices and broader variety may go along with increasing asymmetric information inefficiencies. Market incentives and new technologies are giving rise to new information mechanisms. However, because consumer information has public good characteristics, it cannot be taken for granted that the new information mechanisms are rapidly and efficiently developed in all markets so as to overcome the limitations of the traditional information mechanisms (such as word-of-mouth). Analyzing how efficient the new mechanisms are in responding to the wider information problems raised by the expansion and globalization of markets is an important avenue for further research.

5. Appendix A: Relegated Proofs

5.1. Proof of proposition (1)

Consider expressions (7) and (8). Taking the derivative of (7) with respect to n yields $\frac{dE[SW]}{dn} = V \cdot \frac{\partial Q(n)}{\partial n} - \tau \cdot \frac{\partial D(n)}{\partial n}$, where

$$\frac{\partial Q(n)}{\partial n} = -\frac{1}{n^2} \frac{\left(-\ln\beta\right)\ \delta(1-\rho)A\beta^{\frac{A}{n}}\rho\left(1-\beta\right)}{\left[\rho+(1-\rho)\beta^{\frac{A}{n}}\right]^2} \tag{A.1}$$

$$\frac{\partial D(n)}{\partial n} = -\frac{1}{4n^2}\left[1+\frac{\delta}{\rho+(1-\rho)\beta^{\frac{A}{n}}}+\left(-\ln\beta\right)\ \frac{\delta(1-\rho)\frac{A}{n}\beta^{\frac{A}{n}}}{\left[\rho+(1-\rho)\beta^{\frac{A}{n}}\right]^2}\right] \tag{A.2}$$

Because $0<\beta<1$, $\lim_{n\to 0}\frac{1}{n^2}\beta^{\frac{A}{n}}=0$. Therefore, $\lim_{n\to 0}\left[-\tau\cdot\frac{\partial D(n)}{\partial n}\right]=\infty>\lim_{n\to 0}V\cdot\frac{\partial Q(n)}{\partial n}=0$. Hence for sufficiently small *n*, we find that $V\cdot\frac{\partial Q(n)}{\partial n}-\tau\cdot\frac{\partial D(n)}{\partial n}>0$.

Now, note that both $\frac{\partial Q(n)}{\partial n}$ and $\frac{\partial D(n)}{\partial n}$ are negative and bounded for any $n>0$, and these two derivatives are independent from V and τ. Therefore, given any number of firms $n^0>0$, for sufficiently large V/τ, we find that $V\cdot\frac{\partial Q(n)}{\partial n}-\tau\cdot\frac{\partial D(n)}{\partial n}<0$. Hence, because $\frac{dE[SW]}{dn}$ is continuous in n, there is at least some number of firms n^{SW}, $0<n^{SW}<n^0$, such that $\frac{dE[SW]}{dn}=0$.

Note that if there is a single value of n for which $\frac{dE[SW]}{dn}=0$, then $-V\cdot\frac{\partial^2 Q(n)}{\partial n^2}>-\tau\cdot\frac{\partial^2 D(n)}{\partial n^2}$ must be true at this point (see figure 1). Therefore, this point corresponds to a maximum of social welfare. Alternatively, if there were more than one value of n such that $\frac{dE[SW]}{dn}=0$, only points such that $-V\cdot\frac{\partial^2 Q(n)}{\partial n^2}>-\tau\cdot\frac{\partial^2 D(n)}{\partial n^2}$ correspond to local maxima. Therefore, in any case, the global maximum n^{SW} decreases as a result of an increase in V or a reduction in τ. Graphically, the $-V\cdot\partial Q/\partial n$ curve shifts upward as V increases, whereas the $-\tau\cdot\partial D/\partial n$ curve shifts downward as τ decreases. ■

5.2. Proof of proposition (3)

Using $\lim_{n\to 0}\phi(B\le 0,\ n)=1$ from assumption (3) in (13), we find that $\lim_{n\to 0}Q=\rho+(1-\rho)\beta+\delta$ and $\lim_{n\to 0}D=\frac{1}{4n}\left[1+\frac{\delta}{\rho}\right]$. Hence, $\lim_{n\to 0}\frac{\partial Q(n)}{\partial n}=0$ and $\lim_{n\to 0}\frac{\partial D(n)}{\partial n}=-\infty$. Therefore, for any V and τ, we find that $\lim_{n\to 0}\frac{dSW}{dn}=\lim_{n\to 0}\left[V\cdot\frac{\partial Q(n)}{\partial n}-\tau\cdot\frac{\partial D(n)}{\partial n}\right]=\infty$.

Now, integrating by parts the two expressions in (13) yields:

$$Q(n)=\rho+(1-\rho)\beta+\delta\frac{\rho+(1-\rho)\ \beta}{\rho+(1-\rho)}+\delta\rho(1-\beta)(1-\rho)\ \int_0^1\frac{\phi(B,\ n)}{\left[\rho+(1-\rho)\ \ B\right]^2}dB;$$

$$D(n)=\frac{1}{4n}\left(1+\delta\left[1+(1-\rho)\ \int_0^1\frac{\phi(B,\ n)}{\left[\rho+(1-\rho)\ \ B\right]^2}dB\right]\right).$$

Taking the derivative with respect to *n*, we have:

$$\frac{\partial Q(n)}{\partial n}=\delta\rho(1-\beta)(1-\rho)\ \int_0^1\frac{\partial\phi(B,\ n)/\partial n}{\left[\rho+(1-\rho)\ \ B\right]^2}dB,$$

$$\frac{\partial D(n)}{\partial n}=-\frac{1}{4n^2}\left(1+\delta\left[1+(1-\rho)\ \int_0^1\frac{\phi(B,\ n)}{\left[\rho+(1-\rho)\ \ B\right]^2}dB\right]-n\delta(1-\rho)\ \int_0^1\frac{\partial\phi(B,\ n)/\partial n}{\left[\rho+(1-\rho)\ \ B\right]^2}dB\right).$$

Recall from assumption (3) that $\partial\phi(B,\ n)/\partial n<0$. Hence, for $n>0$, both derivatives $\frac{\partial Q(n)}{\partial n}$ and $\frac{\partial D(n)}{\partial n}$ are negative and bounded. From here on, the argument is the same as in the proof of proposition (1). Because these derivatives are independent from V and τ, given any n^0 and for large enough V/τ, we find that $V\cdot\frac{\partial Q(n)}{\partial n}-\tau\cdot\frac{\partial D(n)}{\partial n}<0$. Hence, by continuity, there exists a number of firms n^{SW}, $0<n^{SW}<n^0$, that maximizes social welfare. Figure 1 is still valid to represent $-V\cdot\frac{\partial Q(n)}{\partial n}$ and $-\tau\cdot\frac{\partial D(n)}{\partial n}$. Again, local maxima correspond to crossings in which $-V\cdot\frac{\partial Q(n)}{\partial n}$ approaches from below. Hence, no matter which of the local maxima is the global maximum n^{SW}, n^{SW} decreases as a result of an increase in V or a reduction in τ. ■

5.3. Proof of proposition (5)

Denote the equilibrium values of *n* and ρ by $n*$ and $\rho*$, respectively. From (19) and (20), we find that $\partial n^*/\partial S>0$ and $\partial\rho^*/\partial n^*\leq 0$ for $S\in[\underline{S},\ \overline{S}]$, with strict inequality for $S\in(S_L,\ \overline{S}]$. As already explained, if the market is small (i.e., for $S\in[\underline{S},\ S_L]$), then there are few firms (i.e., $n \in [1,\ n_L)$), and all firms are *H*-type. Hence, as the market expands within $(\underline{S},\ S_L)$, there is no reduction in expected quality. However, at S_L, consumer information per firm deteriorates to the extent that starting an *L*-type firm becomes profitable. Thus, for $S > S_L$, we find that $\partial\rho^* / \partial S = (\partial\rho^* / \partial n^*) \cdot (\partial n^* / \partial S) < 0$. This reduces expected quality in both periods (see equations [3] and [6]). In addition to this negative effect on quality through the initial share of *L*-type firms, there is the negative effect already analyzed in section 2 namely, that larger *n* results in less information on each firm at the end of the first period, which allows more *L*-type firms to survive into the second period. ■

5.4. Proof of proposition (6)

First, we prove that for a large enough V/τ, there is always a market size $S^{SW} \in [S_L,\ \overline{S})$ that maximizes expected social welfare. Recall that $dE\left[SW\right]/dS = V \cdot MIE(S) - \tau \cdot MPDE(S)$, where $MIE(S) \equiv \left[\frac{\partial Q}{\partial n} + \frac{\partial Q}{\partial \rho}\frac{\partial \rho^*}{\partial n}\right] \frac{\partial n^*}{\partial S} \leq 0$ and $MPDE(S) \equiv \left[\frac{\partial PD}{\partial n} + \frac{\partial PD}{\partial \rho}\frac{\partial \rho^*}{\partial n}\right] \frac{\partial n^*}{\partial S} < 0$ for $S \in [\underline{S},\ \overline{S}]$. These inequalities can be confirmed by recalling assumptions (1) and (2) and $PD = 5D + \left(1+\delta\right)\ c/\tau$ as well as by noting that $\frac{\partial Q}{\partial \rho} = 1 - \beta + \delta \frac{\beta^{A/n}(1-\beta)}{\left(\rho+(1-\rho)\beta^{A/n}\right)^2}$, $\frac{\partial PD}{\partial \rho} = \frac{5}{4n}\frac{\delta\left(1-\beta^{A/n}\right)}{\left(\rho+(1-\rho)\beta^{A/n}\right)^2}$.

As explained in the main text $MIE(S) = 0$ for $S \in [\underline{S},\ S_L)$, and so welfare is increasing in this interval. Then, note that for $S \in (S_L,\ \overline{S}]$, both $MIE(S)$ and $MPDE(S)$ are bounded and strictly negative. Moreover, they do not depend on V or τ. Hence, given $\overline{S}$, for sufficiently large V/τ, we find that $-V \cdot MIE(\overline{S}) > -\tau \cdot MPDE(\overline{S})$. Therefore, because $MIE(S)$ and $MPDE(S)$ are continuous for $S \in (S_L,\ \overline{S}]$, there are two possible cases. Either $-V \cdot MIE(S) < -\tau \cdot MPDE(S)$ at $S = S_L$, in which case there is an optimal market size $S^{SW} \in (S_L,\ \overline{S}]$ such that $-V \cdot MIE(S^{SW}) = -\tau \cdot MPDE(S^{SW})$ (see figure 4.a); or $-V \cdot MIE(S) > -\tau \cdot MPDE(S)$ for $S = S_L$, in which case $S^{SW} = S_L$ (see figure 4.b).

Finally, note that if there is a single crossing between $-V \cdot MIE(S)$ and $-\tau \cdot MPDE(S)$ within the interval $S \in [S_L,\ \overline{S})$, the slopes satisfy $-V \cdot \frac{\partial MIE}{\partial S} > -\tau \cdot \frac{\partial MPDE}{\partial S}$. Therefore, the crossing corresponds to a maximum. However, there could be more than one crossing. In this case, only crossings such that $-V \cdot \frac{\partial MIE}{\partial S} > -\tau \cdot \frac{\partial MPDE}{\partial S}$ correspond to local maxima. In any case, the global maximum decreases as a result of an increase in V or a reduction in τ. ■

6. Appendix B: Alternative Out-of-Equilibrium Beliefs

AS noted in the main text, Salop's (1979) price can be sustained in the first period by appropriate out-of-equilibrium beliefs. In this appendix, we consider some alternative out-of-equilibrium beliefs that may be of interest that lead to lower equilibrium prices. We assume that consumers draw no strategic inference whatsoever about a firm's type from its mere decision to deviate. Then, we consider the potential incentives among *H*-type firma to deviate to decrease prices in the first period in order to increase sales and generate a larger sample of their product. This would increase consumer willingness to pay for the firm's output in the second period.

As in the main text, we restrict our attention to pooling symmetric equilibria. Recall that as a result of assumption (1), the sales of *L*-type firms would be zero in a separating equilibrium. First, we analyze equilibrium in the last period. Let p_i^{II} be firm *i*'s price in the second period and p^{II} be the price for other firms. Consider expected utility of a consumer who is indifferent to buying from *i* versus buying from the nearest alternative firm. Expected utility of this consumer satisfies:

$$V \cdot E(q_i) - p_i^{II} - \tau y_i = V \cdot E(q) - p^{II} - \tau \left(\frac{1}{n^{II}} - y_i \right)$$

where y_i is the distance between this consumer and firm *i*, $E(q_i)$ is expected quality of firm *i*'s output in the second period, $E(q)$ is the expected quality of other firms, and n^{II} is the number of firms in the second period. Thus, firm *i*'s market share in the second period is:

$$Y_i \equiv 2y_i = \frac{1}{\tau}\left(V \cdot E(q_i) - V \cdot E(q) + p^{II} - p_i^{II} + \frac{\tau}{n^{II}}\right)$$

Its discounted expected profit is:

$$\pi_i^{II} = \frac{\delta A}{\tau}\left(V \cdot E(q_i) - V \cdot E(q) + p^{II} - p_i^{II} + \frac{\tau}{n^{II}}\right)\ \left(p_i^{II} - c\right)$$

It is easy to compute prices in the symmetric equilibrium. The first-order conditions for a Nash equilibrium in the second period ($d\pi_i^{II} / dp_i^{II} = 0$) together with symmetry ($E(q_i) = E(q)$ and $p_i^{II} = p^{II}$) yield $p^{II} = \frac{\tau}{n^{II}} - c$, which is Salop's (1979) price.

Let p_i^I be firm *i*'s price in the first period and p^I be the price for other firms. How would an *H*-type firm's second-period expected profit change if it deviated in the first period by setting p_i^I below p^I? This would increase both its first-period sales and consumer willingness to pay for its product in the second period. Note that π_i^{II} is a function of $E(q_i)$, $E(q)$, p^{II}, p_i^{II}, and n^{II}; $\pi_i^{II} = \pi_i^{II}\left(E(q_i),\ E(q),\ p^{II},\ p_i^{II},\ n^{II}\right)$. Hence, we are interested in

$$\frac{d\pi_i^{II}}{dp_i^I} = \frac{\partial \pi_i^{II}}{\partial E(q_i)}\frac{dE(q_i)}{dp_i^I} + \frac{\partial \pi_i^{II}}{\partial E(q)}\frac{dE(q)}{dp_i^I} + \frac{\partial \pi_i^{II}}{\partial p^{II}}\frac{dp^{II}}{dp_i^I} + \frac{\partial \pi_i^{II}}{\partial p_i^{II}}\frac{dp_i^{II}}{dp_i^I} + \frac{\partial \pi_i^{II}}{\partial n^{II}}\frac{dn^{II}}{dp_i^I}$$

Assuming *n* is large, we can ignore the effects of *i*'s decisions on $E(q)$, p^{II}, and n^{II}. Moreover, we note that $n^{II} = n\left(\rho + (1-\rho)\beta^{\frac{A}{n}}\right)$ and $E(q) = V \cdot \left(\frac{\rho + (1-\rho)\beta^{\frac{A}{n}} \cdot \beta}{\rho + (1-\rho)\beta^{\frac{A}{n}}}\right)$, irrespective of p_i^I. In turn, the envelope theorem tells us that $\partial \pi_i^{II} / \partial p_i^{II} = 0$ because we are evaluating this derivative at equilibrium. Hence only the first term in the derivative $\frac{\partial \pi_i^{II}}{\partial E(q_i)}\frac{dE(q_i)}{dp_i^I}$ matters. Denoting firm *i*'s market share in the first period by X_i, we find that

$E(q_i) = V \cdot \left(\frac{\rho + (1-\rho)\beta^{X_i A} \cdot \beta}{\rho + (1-\rho)\beta^{X_i A}} \right)$. Hence the first term in the derivative above is $\frac{d\pi_i^{II}}{dp_i^I} = \frac{\partial \pi_i^{II}}{\partial E(q_i)} \frac{dE(q_i)}{dp_i^I} = \frac{\partial \pi_i^{II}}{\partial E(q_i)} \frac{dE(q_i)}{dX_i} \frac{dX_i}{dp_i^I}$.

Now, let us analyze price decisions in the first period. Consider expected utility for a consumer who is indifferent to buying from *i* versus buying from the nearest alternative firm. Denoting the distance between this consumer and firm *i* by x_i, we have:

$$V\left(\rho + (1-\rho)\beta\right) - p_i^I - \tau x_i = V\left(\rho + (1-\rho)\beta\right) - p^I - \tau\left(\frac{1}{n} - x_i\right)$$

Hence $X_i = 2x_i = (p^I - p_i^I + \frac{\tau}{n})/\tau$. Thus, firm *i*'s first-period profit is $\pi_i^I = \frac{A}{\tau}\left(p^I - p_i^I + \frac{\tau}{n}\right)\left(p_i^I - c\right)$. Then, the first-order condition from maximizing total expected profit with respect to p_i^I is:

$$\begin{aligned} \frac{d\pi_i^T}{dp_i^I} &= \frac{d\pi_i^I}{dp_i^I} + \frac{d\pi_i^{II}}{dp_i^I} \\ &= -\frac{A}{\tau}(p_i^I - c) + \frac{A}{\tau}\left(p^I - p_i^I + \frac{\tau}{n}\right) \\ &\quad + V\frac{\delta A}{\tau}\frac{\left(\ln\beta\right)\ \ \beta^{X_i A} A(1-\rho)\left(1-\beta\right)\ \ \rho}{\left(\rho + (1-\rho)\beta^{X_i A}\right)^2}\frac{1}{\tau}\cdot\left(p_i^{II} - c\right) = 0 \end{aligned}$$

Note that we take into account the computations on $\frac{d\pi_i^{II}}{dp_i^I}$ above. Substituting the expression above for p_i^{II} and using symmetry (i.e., $p_i^I = p^I$ and $X_i = 1/n$) yields:

$$p_i^I = \frac{\tau}{n} - c + \frac{V}{\tau}\delta\left(\ln\beta\right)\ \ A(1-\rho)\left(1-\beta\right)\ \ \rho\frac{\beta^{\frac{A}{n}}}{n\left(\rho + (1-\rho)\beta^{\frac{A}{n}}\right)^3}$$

Recall that Salop's (1979) price is $P_t = \frac{\tau}{n_t} + c$. Hence, we find that $p^I < P$; note that the last term in the expression above is negative. From this expression, define $\Delta CS \equiv \frac{V}{\tau}\delta\left(-\ln\beta\right)\ \ A(1-\rho)\left(1-\beta\right)\ \ \rho\beta^{\frac{A}{n}}/n\left(\rho + (1-\rho)\beta^{\frac{A}{n}}\right)^3 > 0$. Consumer surplus in this equilibrium can be computed by adding this new term ΔCS to expression (10).

Therefore, consumer surplus is larger in the equilibrium under the alternative out-of-equilibrium beliefs considered in this appendix.

Now, we can show that proposition (2) holds in this equilibrium. Recall that the key point in the proof of proposition (2) was to show that dCS/dn is positive for *n* sufficiently close to 0 and negative thereafter if V/τ is sufficiently large. We now prove that the derivative of the new additional term ΔCS in consumer surplus with respect to *n* is positive for sufficiently small *n* and negative for sufficiently large *n*. We find that:

$$\frac{d\Delta CS}{dn}=\frac{V}{\tau}\frac{\delta(-\ln\beta)\ \ A(1-\rho)(1-\beta)\ \ \rho}{n^2\left(\rho+(1-\rho)\beta^{\frac{A}{n}}\right)^4}\beta^{\frac{A}{n}}\left[\frac{A}{n}(-\ln\beta)\ \left(\rho-2(1-\rho)\ \ \beta^{\frac{A}{n}}\right)-\left(\rho+(1-\rho)\beta^{\frac{A}{n}}\right)\right]$$

This derivative is continuous and its sign only depends on the sign of the term within square brackets. Note that this term is positive for *n* sufficiently close to 0 and negative for sufficiently large *n*. Therefore, for large enough V/τ expected consumer surplus is maximized for a finite (initial) number of firms n^{CS}. Beyond n^{CS}, the positive price and distance effect of a larger number of firms is outweighed by the negative effect of lower expected quality.

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