Diversity and demand externalities: How cheap information can reduce welfare[1]

Heski Bar-Isaac
New York University

Guillermo Caruana
CEMFI

Vicente Cuñat
Universitat Pompeu Fabra

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Abstract

Goods and services vary along a number of dimensions independently. Customers can choose to acquire information on the quality of some dimensions and not others. Their choices affect firms' incentives to invest in quality and so lead to indirect externalities in consumers' choices. We illustrate these ideas in a simple model with a monopolist selling a product with two characteristics, investments in quality with stochastic realizations and heterogeneous consumers. A fall in the cost of acquiring information on the quality of one characteristic leads more consumers to verify that characteristic. Consequently, the firm may under-provide quality on the other. This may paradoxically reduce consumer surplus, profits and welfare. Our discussion concludes with a number of potential extensions and applications of the basic framework.

When shopping for goods with multiple characteristics that are not easily observable, consumers' decisions on what to observe and whether to buy affect the type of good offered and, indirectly, other consumers' welfare. Think of a prospective student deciding on a business school. She is likely to be concerned by her expected salary on graduation and also by long-term career prospects. Business schools can tailor their programs in ways that affect these differently. Historically, students have relied on talking to alumni and on other independent research to gain relevant information. Business school guides and

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rankings have made it easier for students to learn average salaries on graduation but have had little effect on the information available on other dimensions. As a consequence, more students may only investigate and make decisions based on average starting salaries. This has induced business schools to tailor their programs to the rankings. As noted by popular commentators, the overall effect of this process may be detrimental for students.[2] Similarly, the easy availability of Robert Parker's 100-point wine ratings—while benefiting many as "a democratic, no-nonsense way of jettisoning the elitist jargon that veils quality from the consumer" (Darlington (2005))—has also been criticized on the grounds that "Part of the charm and beauty of wine is its idiosyncrasy, but when everybody tries to hit the same sweet spot, it's like making soda pop." (Joel Peterson quoted in Darlington (2005)).

These are just two examples of a more general phenomenon. There are many goods and services that are, by nature, multidimensional. Given that it is costly to verify all the characteristics of a good, consumers often make purchase decisions based only on partial information. Further, firms have to decide whether and how much to invest in the quality of different dimensions. These decisions take into account that consumers are heterogenous in their search behavior. As a consequence there are indirect externalities among consumers: In equilibrium, their individual choices affect firm investments and thereby other consumers. Our contribution in this paper is to highlight this mechanism, its implications for investment incentives, consumer surplus, and welfare; and in particular, to show that a drop in the costs of acquiring information can lead to a welfare loss.

We consider a market in which a monopolist sells a good with two characteristics, investing separately in the quality of each. Investments lead to uncertain realizations, which can only be observed by customers at a cost. So, customers may pay to assess quality before deciding whether or not to buy the good. We show that a fall in the cost of assessing one of the characteristics affects welfare and in particular, it may be detrimental. Underlying this result is the observation that there are inherent indirect externalities in consumers' choices of which characteristic to assess. A simple revealed preference argument guarantees that if the firm's behavior is fixed then a fall in the costs of assessing one characteristic unambiguously raises consumers' welfare. This is not the case when the firm can vary its investments in response to the fall in search costs. Consumers' expected choices affect

[2] Schatz (1993), for example, states that: "the rankings resulting from the surveys are too one-dimensional to be taken seriously. Most likely, no single MBA program is best for everyone, and almost every program is best for someone. The match has to be individualized." (See also Education & Social Science Library (2005) for a wide-ranging survey of critiques of school rankings.) In itself this observation need not imply adverse welfare consequences; however, Schatz argues that: "people foolishly tend to believe that there is significance to the order in which the schools appear". Our model assumes that all agents are fully rational but that information is costly. Without having to assume that people are foolish, we show that the rankings are relevant but, through their easy availability, can have adverse consequences.

the producer's investments in the quality of each of the dimensions. However, customers cannot commit to their choices and do not take into account their cumulative effect on the firm's behavior.

Specifically, changes in aggregate consumer behavior affect welfare in two different ways.

First, a customer may assess a dimension, choose to buy the product and, on consuming, find herself enjoying quality on the other dimension that she had not assessed. This quality results from firm investments that cater to customers who assess that other dimension. Through this externality, greater diversity in consumer behavior increases welfare.

The second effect has an opposite implication. A customer may assess a dimension in which quality is not realized and consequently choose not to purchase, even though the firm has produced quality on the other unassessed dimension to attract a different type of buyer. This quality, which is produced but not consumed, suggests that diversity in consumer behavior may also have a negative effect on welfare.

The effect of a fall in the customers' assessment costs on the diversity of consumer behavior depends on the initial conditions. Suppose first that most consumers are assessing one characteristic, then a fall in the cost of assessing the other characteristic would lead to greater diversity in consumer behavior. Alternatively, if initially most consumers assess the second characteristic, then this fall in costs reduces diversity.

Overall, the effect of a fall in search costs on welfare is ambiguous. Such a fall can either reduce or increase the diversity of consumer behavior which, in turn, can either increase or reduce welfare.

The papers most closely related to ours in spirit are Dranove and Satterthwaite (1992), which presents a theoretical framework, and Dranove et al. (2001), which empirically highlights negative welfare consequences of quality "report cards" on physicians. These papers focus on producer behavior and use a general aggregate demand without considering individual consumer behavior explicitly. Meanwhile, our focus is on consumers who play an active role when choosing which information to acquire, and highlight how their individual decisions affect each other.

This work is also related to the multi-tasking literature that starts with Holmstrom and Milgrom (1994), but there are crucial differences. They show that in a moral hazard multi-task environment it is difficult to provide strong and well-balanced incentives. If efforts are substitutes in the cost function, strengthening incentives in one dimension leads to lower effort on the other. The driving forces in our paper are different for the following reasons: (i) in contrast to their mechanism design approach, we analyze a situation in which firm's incentives arise endogenously from individual consumers decisions in a market setting; (ii) we study a fundamentally incomplete contract setting, as both parties lack

important commitment abilities; and (iii) we do not assume substitution in the cost of effort.[3]

There are several papers that have highlighted other mechanisms through which allowing for more information can be damaging for welfare. Schlee (1996) shows that making more information publicly available might also benefit strategic rivals.[4] Kessler (1998) illustrates that committing to an information structure can change the resulting choice of an explicit contract.[5] Finally, Glazer and McGuire (2005) show that revealing a quality index rather than its constituents can in effect reduce the firm's feasible choices in such a way as to counter-act monopoly power.

Our discussion is also related to wider discussions on the benefits of diversity. Waldfogel (2003) treats this issue empirically and focuses on product proliferation with heterogeneous consumers. In his framework consumers benefit from the presence of more consumers with similar preferences. We can get a contrasting result: In our setting verifying quality is costly and therefore there is a benefit from diversity in consumer search, which arises from underlying diversity in consumer preferences. Further, many formal models in economic geography directly incorporate a benefit of diversity through complementarity in the production function. Rather than highlighting the role of diversity in production, our arguments stress that there may be benefits of diversity on the demand side. That such benefits play an important role in large multi-cultural cities has been eloquently if informally suggested in Diamond et al. (2004). In other related work, Glaeser et al. (2001) have discussed the importance of amenities and the growth of "consumer cities"; our framework can provide a micro-foundation and suggests that diversity per se may play an important role.

1 Model

We introduce a model with a monopoly producer of a single complex good, which is priced at p. This good has two different characteristics or dimensions (a and b). Every unit of the good can be of high or low quality in each of its two dimensions. The effective quality realization of each of them is stochastic.[6] For one of the characteristics the probability of high quality is fixed, but for the other it depends on the firm's investment.[7] Consumers

[3] Indeed, the model delivers the result considering an investment decision in only one dimension.

[4] See also Sakai (1985), Gal-Or (1988), Mirman et al. (1994) and Harrington (1995).

[5] Building on similar intuitions arising in Cremer (1995) and Dewatripont and Maskin (1995).

[6] The stochastic realization can be viewed either as reflecting the nature of the production technology or as reflecting idiosyncratic consumer tastes. In this latter case, higher investments in quality cater to a wider range of such tastes.

[7] It is reasonable to think that firms choose how much to invest in each of the dimensions. This is a simplifying assumption that leads to an analytically simpler model without changing any of the substantial results.

incur costs in determining the quality of an attribute before making a purchase decision.

Timing is as follows:

1. The firm invests e in the quality of attribute b.
2. Each customer, without observing the firm investment decision, chooses to assess the quality realization on none, one, or the other attribute.
3. Each customer chooses whether or not to buy the good.

Specifically we make the following assumptions with respect to the firm and consumers:

Firm

The firm invests $e \geq 0$ in the quality of attribute b at a cost of $\frac{e^2}{4}$. This is a sunk cost that is incurred regardless of the number of sales. The marginal cost of production is 0.

Production leads to stochastic quality realizations, where $q_i \in \{0, 1\}$ denotes the quality realization of the good in attribute $i \in \{a, b\}$. While the probability of high quality, $q_a = 1$, in attribute a is exogenous, for attribute b it depends on the firm's investment. Specifically, we suppose that $Prob(q_a = 1) = \frac{1}{2}$ and $Prob(q_b = 1) = e$. Note that stochastic realizations of quality give consumers some incentives for assessing it.

The firm's only choice is the level of investment in quality b (which is e), since we assume that the price of the good p is exogenous. The exposition is much less straightforward but similar effects arise and similar qualitative results can be shown when the price is endogenous. Moreover, there are important markets, including healthcare and state-funded education, where the assumption of an exogenous price from the perspective of firms and consumers may be appropriate.

Consumers

There is a continuum of *ex-ante* heterogeneous consumers indexed by t, where t is uniformly distributed on $[0, 1]$.[8] Consumer t when buying one unit of the good with quality q_a on attribute a and q_b on attribute b at a price p gets a utility of $tq_a + (1 - t)q_b - p$. That is, all consumers value both dimensions of the good, but consumers with a high t give more importance to attribute a while consumers with a low t give more importance to attribute b.

Consumers cannot directly observe the quality of a good in each dimension; however, they can incur some search costs to assess the quality realization of either dimension. In particular, by incurring a cost A, a consumer can perfectly determine whether the quality

[8] We present a model in which consumers are heterogeneous in tastes. Similarly one could think of consumers with homogeneous tastes who are heterogeneous in their search costs.

on dimension a is high or low, and by incurring a cost B she can perfectly learn the quality on dimension b.

We suppose that the consumer can search either in one dimension or the other. She may also choose to buy without assessing quality or choose to neither assess quality nor buy. We preclude the possibility of searching on both dimensions before making a decision.[9]

If the realization of the quality and the consumer's assessment behavior leads the consumer to purchase a good of quality (q_a, q_b) at the price p, her overall utility can be written as:

$$U_t = tq_a + (1-t)q_b - p - AI_{s=a} - BI_{s=b} \tag{1}$$

where $I_{s=a}$ takes the value 1 if and only if the consumer assessed dimension a and takes the value 0 otherwise; $I_{s=b}$ is similarly defined. If the consumer does not buy the good, her utility is simply

$$U_t = -AI_{s=a} - BI_{s=b}. \tag{2}$$

We now move on to characterize the equilibrium search strategies of consumers and the firm's quality investments.

2 Equilibrium analysis

We characterize the optimal behavior, first of consumers then of the firm and bring these together to determine equilibrium.

2.1 Consumers

In general, a consumer of type t has four choices: assessing characteristic b, assessing characteristic a, buying without assessing, and simply not buying the good.[10] Among the four, she chooses whichever gives highest utility. What is crucial for determining the firm's behavior is the fraction of consumers who assess characteristic b. Suppose that there is some consumer T who is indifferent between assessing b and the best of her other choices, when anticipating that the firm will invest e. Assuming that T is interior then, it is implicitly

[9] This last assumption is for simplicity and is not crucial: For an agent assessing characteristic b, conditional on doing so there is less to be gained from searching on a, and so the propensity to do so would be diminished. Thus even if agents had the opportunity to search on both dimensions, there would still be consumers who switch from searching on a to searching on b; and these are the key driving force in our analysis. Moreover, the assumption may be appropriate in itself if consumers face a time constraint that makes searching on a second dimension prohibitively expensive (or if there are other decreasing returns to searching on both dimensions).

[10] Note that a consumer who decides to assess one of the characteristics purchases if and only if the realization is high. Otherwise, she would be better off taking the same unconditional purchasing decision without paying the search cost.

defined by the equation:

$$e(1-T+\frac{1}{2}T-p)-B=\max\{\frac{1}{2}(T+(1-T)e-p)-A,\frac{1}{2}T+(1-T)e-p,0\} \quad (3)$$

Note that consumers with $t<T$ prefer to search on dimension b and purchase if and only if they discover high quality on that dimension. In our analysis, we focus on instances in which all consumers with $t>T$ search on dimension a.[11] In these circumstances, assessing a gives the highest value among the alternatives on the right hand side of Equation (3) and we obtain:

$$T=p\,(1-2e)+e-2(B-A). \quad (4)$$

Note that the threshold T can take any value between zero and one. A value $T=0$ would correspond to all agents searching on dimension a, while $T=1$ would correspond to all agents searching on dimension b.

2.2 Firm

The firm chooses an investment in quality e, in order to maximize profits given the anticipated equilibrium behavior of consumers. A proportion T of the consumers search on dimension b, buying whenever they find high quality on that dimension (which occurs with probability e and so is influenced by the firm's choice of investment). The remaining $(1-T)$ consumers search on dimension a and buy if and only if they find high quality (which occurs with probability $\frac{1}{2}$).

The firm's problem can be expressed as:

$$\underset{e}{max}\Pi=((1-T)\frac{1}{2}+Te)p-\frac{e^2}{4}. \quad (5)$$

The first order condition with respect to e can therefore be written down as follows:

$$Tp-\frac{1}{2}e=0. \quad (6)$$

In particular, we obtain:

$$e=2pT. \quad (7)$$

[11] We later discuss other possible equilibria.

2.3 Equilibrium

Conditions (7) and (4) determine the equilibrium values of T and e in terms of the exogenous parameters of the model (A, B and p):

$$T = \frac{2(A-B)+p}{1-2p+4p^2} \tag{8}$$

$$e = 2p\frac{2(A-B)+p}{1-2p+4p^2}. \tag{9}$$

We can use the equilibrium values of T and e to compute the value of expected profits, consumer surplus, and total welfare:

$$\Pi = p((1-T)\frac{1}{2} + Te) - \frac{e^2}{4} \tag{10}$$

$$CS = \int_0^T (e(1-x+\frac{x}{2}-p) - B)dx + \int_T^1 (\frac{1}{2}(x+(1-x)e-p) - A)dx \tag{11}$$

$$W = \Pi + CS, \tag{12}$$

where the first integral in the consumer surplus corresponds to the fraction T of consumers who search on dimension b and the second corresponds to the fraction of consumers who search on dimension a. Adding together expressions (11) and (10), substituting $e = 2pT$ from Equation (7), and simplifying, we can express total welfare as:

$$W = \frac{1}{4}(1-T^2+2pT) + p(1-p)T^2 - A(1-T) - BT. \tag{13}$$

The relationship between welfare and search costs is complex, as it depends not only on the direct effects of the cost of searching (A or B), but also on the aggregate search behavior of consumers (summarized by T) and the change in quality provision by the firm ($e = 2pT$). We characterize these effects in detail in Section 3 where different net effects may be observed.

Note that alternative equilibria may exist simultaneously (for example, one in which there is no investment and no assessment of dimension b; or another in which the threshold consumer T is indifferent between assessing b and not buying the good). However, it can be verified that in the parameter range we consider below, the equilibrium studied here generates both higher consumer surplus and higher profits than any other equilibrium.

3 Comparative Statics

Our interest is in the comparative statics of welfare with respect to A, the cost of assessing attribute a. We consider the case where e and T are interior and all agents assess one or

other of the characteristics. Equation (13) defines welfare, and Equations (8) and (9) fully characterize equilibrium. Rather than differentiating W directly, we begin by examining how a rise in the cost of assessing attribute A affects the firm's profits and the consumer surplus. Beginning with firm profits:

$$\frac{d\Pi}{dA} = \frac{\partial \Pi}{\partial T}\frac{dT}{dA} + \frac{\partial \Pi}{\partial e}\frac{de}{dA} = \frac{\partial \Pi}{\partial T}\frac{dT}{dA}, \tag{14}$$

since $\frac{\partial \Pi}{\partial e} = 0$, as e is chosen to maximize the firm's profits. Thus,

$$\frac{d\Pi}{dA} = p(e - \frac{1}{2})\frac{2}{1 - 2p + 4p^2} \tag{15}$$

Given that $\frac{dT}{dA} = \frac{2}{1-2p+4p^2} > 0$, it follows that $\frac{d\Pi}{dA} > 0$ if and only if $e > \frac{1}{2}$. This result captures the inefficiency of quality produced but not consumed: a rise in the cost of assessing a drives more consumers to assess characteristic b, this increases firm profits whenever high quality is more likely to be realized on characteristic b (that is where $e > \frac{1}{2}$), and reduces profits in the opposite case. Thus $\frac{d\Pi}{dA}$ may be either positive (when e is sufficiently high, which requires many consumers to be searching on dimension b, which in turn is likely when A is high) or negative. As the equilibrium level of investment increases with A, overall profits may be non-monotonic in A.

Next turning to consumer surplus, the total derivative with respect to A yields:

$$\frac{dCS}{dA} = \frac{\partial CS}{\partial A} + \frac{\partial CS}{\partial T}\frac{dT}{dA} + \frac{\partial CS}{\partial e}\frac{de}{dA} \tag{16}$$

We consider each term of this expression in turn.

First, the direct effect of a rise in the cost of assessing characteristic A is negative: for those assessing characteristic a an increase in the cost of doing so reduces their utility. Analytically, $\frac{\partial CS}{\partial A} = -(1 - T)$.

Next, $\frac{\partial CS}{\partial T} = 0$, that is, there is no direct effect on consumer surplus of a marginal increase in T. Such an increase shifts the T consumer, previously assessing attribute a, to assess attribute b instead. But this consumer was indifferent between searching on one or the other dimension, thus her welfare is not affected.

Finally, the indirect effect of raising A through the firm's investment e on consumer surplus is unambiguously positive. The effect of a change in A in the equilibrium investment e is positive, as one can verify from Equation (9). Given this, for those assessing b, there is a greater likelihood of finding quality, and for those assessing a, there is a higher likelihood of enjoying quality on the dimension that they do not assess. Note that this is the externality

that generates a "benefit of diversity" to consumers, alluded to in the introduction.[12] More formally,

$$\frac{de}{dA} = \frac{8p^2}{1-2p+4p^2} > 0 \tag{17}$$

$$\frac{\partial CS}{\partial e} = \int_0^T (1 - \frac{x}{2} - p)dx + \int_T^1 \frac{1}{2}(1-x)dx = T(\frac{1}{2} - p) + \frac{1}{4} > 0 \tag{18}$$

The second integral is positive trivially. Consider the first: $(1 - \frac{x}{2} - p)$ must be positive in the range $[0, T]$ for those consumers to have an incentive to search.[13]

Putting these elements together, overall we can write:

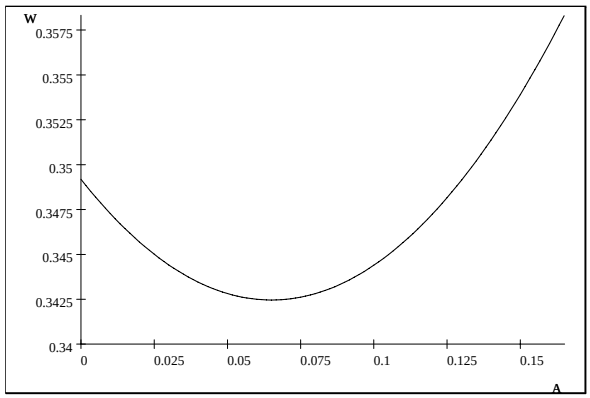
$$\frac{dCS}{dA} = -(1-T) + (T(\frac{1}{2} - p) + \frac{1}{4})\frac{8p^2}{1-2p+4p^2}. \tag{19}$$

Since the first term is negative and the second term is positive, in general, we cannot sign $\frac{dCS}{dA}$, and, indeed, it may be non-monotonic. Note, however, that when T is close to 1 (that is most consumers are searching on attribute b), which is likely when A is relatively high, the direct effect of a change in A is negligible, and so consumer surplus increases in A. Conversely, as can readily be verified, if most consumers are searching on dimension a, the direct effect dominates and consumer surplus decreases in A.

We can finally turn to welfare. The discussion above allows us to conclude that welfare may be non-monotonic in the cost of assessing a. In particular, we have argued that both profits and consumer surplus are likely to be increasing in A when the cost of assessing quality on dimension a is relatively high; and decreasing when A is relatively low. Therefore, this should also hold for welfare. We illustrate that this is indeed the case when $p = 0.6$ and $B = 0.05$ through the following graph.

[12] In the model since the probability of quality in characteristic a is fixed, it is not diversity *per se* that benefits consumers through these externalities, but rather that more assess characteristic b and so lead the firm to invest more in this characteristic. Allowing for investments in both dimensions allows for a benefit of diversity *per se*.

[13] Note that from Equation (3) $e(1 - \frac{t}{2} - p) \geq B > 0$ at $t = T$ in equilibrium and further note that it is increasing in t in the range $[0, T]$.



Wefare for different search cost values

Decomposing the effect on welfare overall into the effects through firm profits and consumer surplus separately, it can further be shown that both profit and consumer surplus are non-monotonic in the cost of assessing attribute a; and, in particular, that both are decreasing for sufficiently low values of A and increasing for high values.[14]

This achieves the main goal of this paper. We have shown that a reduction of the search costs can be detrimental for welfare. This is the result of a lack of coordination, or commitment, by all parties: the firm and every single consumer. If A goes down, all parties expect others to put "less attention" to dimension b. These expectations reinforce each other and, as a consequence, on equilibrium there is both less effort (by firms) and less searching (by consumers) devoted to characteristic b. This reduces the value of the resulting good and ends up hurting everyone.

4 Final Remarks

The model highlights a number of effects at work in consumer markets for goods with multiple dimensions in a stylized and transparent way. We have stressed, in particular, two counter-acting effects of increasing the diversity in consumer behavior. First, consumers benefit from enjoying quality on characteristics that they had not assessed; and second, high quality realizations may be left undiscovered. Since consumers have no way of internalizing the effect of their aggregate choices on the firm's investment in quality, a change in these choices induced by a fall in the costs of information on product quality can reduce welfare. This seems to accord with the evidence that there have been adverse welfare effects in the context of health markets (Dranove et al (2001)), and, with the popular perception in the cases of business schoosl and wine rankings.

In addition, the model serves as a starting point for a number of interesting extensions.

[14] Specifically, here, profit takes its minimum at $A = 0.001$ and consumer surplus takes its minimum at $A = 0.147$.

First, the model can be extended to allow the firm to choose investments in each of the quality characteristics. One can show that the qualitative insights of this paper still apply; however, at a cost of a more complicated analysis. It is worth reiterating that even in this case, when the firm has to allocate effort to a number of different tasks, the implied welfare inefficiencies would not be a consequence of the multi-tasking setting. As we highlighted in the introduction, we focus on market forces, as opposed to the typical principal-agent contracting framework considered in Holmstrom and Milgrom (94), and do not rely on any substitutability across tasks in the firm cost technology. Such subsititutability in the cost function, if there were any, would only reinforce our effects.

Another natural extension of the model is to allow for competition among producers. Competition in quality provision can be studied within our framework. It generates similar results without bringing additional economic insights, and complicates the analysis substantially. Competition in prices is a much more subtle extension. Depending on technical assumptions regarding the timing of the decisions and the information gathering technology considered one encounters different complications, including signalling and existence of equilibria.

Next, interesting dynamic implications arise if we allow consumer strategies and firm investments to change at different rates. In particular, a fall in the cost of acquiring information could initially raise consumer surplus and overall welfare. However, the subsequent reaction of the firm to the consumers' new search behavior may lead to a reduction in welfare in the long run. This will be the case even when all agents are fully aware of these mechanisms due to the inability of consumers to coordinate and commit to an aggregate assessment strategy. This might explain why policies or innovations such as the introduction of school league tables in the UK, while initially welcomed are eventually reviled.

We have treated the cost of acquiring information as exogenous, there are a number of ways in which one could envisage endogenizing it. In particular, it would be interesting to extend the model and allow the firm to affect the consumer assessment technology, and in particular its costs. This may lead to predictions on whether these channels would be used to highlight, or to the contrary, obfuscate particular product characteristics. This seems to be a salient issue in reality. Think for example of informative advertising, or commitments to regular information disclosure, or, returning to the business school example of the introduction, on HBS and Wharton's recent decision not to convey any information to one of the rankings (Bradshaw (2005)).

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