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Publisher: Institute for Operations Research and the Management Sciences (INFORMS)
INFORMS is located in Maryland, USA

Manufacturing & Service Operations Management

Publication details, including instructions for authors and subscription information:
http://pubsonline.informs.org

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To cite this article:
Tian Li, Shilu Tong, Hongtao Zhang (2014) Transparency of Information Acquisition in a Supply Chain. Manufacturing & Service Operations Management 16(3):412-424. http://dx.doi.org/10.1287/msom.2014.0478

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MANUFACTURING & SERVICE OPERATIONS MANAGEMENT
Vol. 16, No. 3, Summer 2014, pp. 412–424
ISSN 1523-4614 (print) | ISSN 1526-5498 (online)

http://dx.doi.org/10.1287/msom.2014.0478
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Transparency of Information Acquisition in a Supply Chain

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A firm hires a consultant to acquire demand information. The outcome of information acquisition may turn out to be successful such that the firm learns much about the market demand, thus becoming "informed," or unsuccessful such that it learns very little about the market demand, thus remaining "uninformed." After the outcome becomes clear, the firm knows its information status, informed or uninformed, and the information content if informed. The client firm usually requires strict confidentiality that forbids the consultant to make any disclosure about the information acquisition, believing that greater informational advantage will surely be to its own benefits. As a result, neither the information content nor the information status is known to any third party. But should the firm always care so much about strict confidentiality? Will it be beneficial if the firm's information status, but not the information content, is known to its partners or any other firms? We investigate this issue in the context of a two-tier supply chain. A manufacturer offers a menu of contracts for supplying a product to a retailer who sells it in a market with random demand that has a known continuous distribution. The retailer hires a consultant to acquire demand information, with uncertain outcome. With probability t, the retailer becomes informed about the market demand, and with probability $1-t$, he remains uninformed, where the probability t can be regarded as representing the retailer's information acquisition capability. We find that disclosing its information status benefits the retailer if its information acquisition capability is less than stellar and the market variability is intermediate. Our investigation shows that there are benefits that are foregone by following strict confidentiality but can potentially be recovered by switching to a policy of partial confidentiality.

Keywords: transparency; market research; confidentiality; supply chain
History: Received: May 16, 2011; accepted: January 6, 2014. Published online in *Articles in Advance* May 5, 2014.

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1. Introduction

Motivated by the belief that information creates value through enabling better business decisions, firms invest in information systems and make efforts to acquire information. Accurate information obtained from market research can be of enormous value to a firm in gaining and maintaining its competitive edge. Existing research on the value of information usually assumes that information has been or can be obtained, and that the availability of information is unambiguous—firms either have no access to the information at all or always obtain the information. In reality, however, the availability of information can be uncertain, because efforts to acquire information may or may not produce useful insight. For example, a retailer who conducts market research may succeed or may fail in actually obtaining useful information about customer preferences or potential demand before the selling season. Any research that does not add much to learning or understanding in time can be said to have failed. The consequence of market research failure is one of lost opportunities. There are a number of reasons that lead to the failure of information acquisition. If market research is too large and time consuming, the information acquisition may fail to give the results needed in the time they are needed. A failure to apply brainpower and thinking time—not primarily a failure of techniques—is the main cause of systemic "failures" of market research, according to Gordon (2010), the managing partner at Gordon and McCallum. Human resource constraint, especially when the availability of the experienced senior executives is very limited, is another reason why a market research may fail. Some customer research through focus groups or surveys looks only at customers' surface attitudes and misses the subconscious associations at work in consumers' minds (Zaltman et al. 2008). A related issue is the difference between data and information. Modern data collection technologies have led to an explosion in both the scope and volume of customer and market data

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that are accessible to firms. However, a large volume of data does not translate into much useful insight if the firm lacks the expertise or time to do the right investigation that provides meaning to the numbers, resulting in "big data, small information."

One of many different means to acquire demand information is to hire a market research agency or consultancy, for the latter's depth of specific knowledge in certain areas and breadth of overall knowledge in market research. That, however, does not guarantee that the market research will not fail. According to Gordon (2010), there are some common faults leading to the consultancy's failure in market research, such as designs and outputs that bear only a moderate relationship to the brief that was given, or questionnaires that ask many questions on very peripheral issues but only one or two fairly unimaginative questions on the key client objective. Another cause may be that the planned time or budget is found to be insufficient when the research has grown considerably in scope while half way through (and as such has to be aborted). Therefore, as a client of the consultancy, the firm may become much better informed of the market demand when the market research turns out to be successful, or he may remain poorly informed when the market research turns out to be unsuccessful, before the selling season.

We define the client firm's *information status* about the market demand as being informed or uninformed, depending on whether the hired consultancy succeeds in finding much new insight about the demand through the commissioned market research. Information status (Has the firm learned much about the market demand?) is not the same as information content (Is the market demand high or low?). Although both the information status and the information content are the client firm's private knowledge, the question we investigate is the following: Should the firm disclose its information status, but not the information content, to its partners or any other firms?

Disclosure or nondisclosure of information status can be roughly labeled as partial or strict confidentiality. The contrast of the two regimes can be likened to the possession of private or secret information. We say that a firm has certain private information if it alone may know the content of information but others know whether the firm has the information or not. A firm has certain secret information if it alone may know the content of information and others do not even know whether the firm has the information. The question we address in this paper is about the impact of making secret information private and the conditions under which such impact benefits the disclosing firm.

Most research on information sharing or disclosure is concerned with sharing the specific content of information, e.g., sales data or demand forecast. The issue of disclosing the information status, but not the information content, has received little attention. One reason for this may be that practitioners are not aware of the business impact of such disclosure. Another reason may be the strict nondisclosure and confidentiality that is practiced by market research consultancies as an unquestioned professional standard. Many professional market research associations even make such strict confidentiality a basic requirement for its member practitioners. Therefore, as a common practice, consultancies do not release or publish research findings without the consent of their clients. The client firm, on the other hand, usually requires a confidentiality agreement that forbids the consultant from disclosing anything about information acquisition, including the information status, to other companies, in the belief that greater informational advantage so preserved will surely be to its own benefits.

However, is strict confidentiality always good for the client firm? Could the firm actually benefit if its information status is known to its partners or any other firms? What if terms of the confidentiality agreement leave out the information status such that the consultancy may, inadvertently or purposefully, reveal the information status to its other client firms or some other third party? We investigate this issue in the context of a two-tier supply chain in an attempt to discover *potential benefits that are foregone by following strict confidentiality*.

A manufacturer (her) supplies a product to a retailer (him) who sells it to a market with random demand. Before the start of the selling season, the retailer makes an attempt to acquire demand information, with uncertain outcome—the acquisition attempt may or may not yield very useful information. With probability $t < 1$, the retailer learns much about the market demand (observes a high quality demand signal), thus becoming very informed; with probability $1 - t$, the retailer learns very little about the market demand (observes a low quality demand signal), thus remaining very much uninformed. That the probability t, which we refer to as the retailer's *information acquisition capability*, is less than one reflects the reality that market research has uncertain outcomes and does not always generate much new insight into potential demand.

We say that the retailer's information acquisition is *transparent* to the manufacturer, if the manufacturer observes the retailer's information status (informed/uninformed), or *nontransparent* otherwise. We refer to the two situations as the transparency scenario and the nontransparency scenario, respectively. In each scenario, the manufacturer, who has no access to the content of the demand information, offers a menu of supply contracts for the retailer to choose from. The retailer's incentive to disclose his information status and the impact of this disclosure

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to the supply chain firms can be assessed by profit comparison between the two scenarios.

This paper is related to the literature that examines how the downstream firm's forecasting capability impacts contract design and firms' performances. Miyaoka and Hausman (2008) and Taylor and Xiao (2010) study this issue in a newsvendor-type setting under a wholesale price contract and a quantity/payment bundle contract, respectively. There is, however, no information acquisition uncertainty in their models. Lariviere (2002) compares buy-back and quantity flexibility contracts in a newsvendor-type model when the downstream firm may improve his demand information at a cost. He assumes that the outcome of downstream information acquisition is either always transparent or always nontransparent to the upstream firm. Our paper differs in that we study the effect of transparency of information acquisition by comprehensively comparing the contracts and firms' performances when the information acquisition outcome is transparent to the manufacturer with those when it is nontransparent to the manufacturer.

Our work is also related to the literature of screening models in supply chain contracting under asymmetric information. Cachon (2003) provides an excellent review of the literature. Özer and Wei (2006) study contracts to ensure credible demand information sharing and to coordinate the supply chain. Ha (2001) and Corbett et al. (2004) investigate the contract design problem when the downstream firm has private cost information. Ha and Tong (2008) consider two competing supply chains and address the issue of contracting and information sharing under demand uncertainty. These papers do not consider information acquisition. In contrast, our work incorporates downstream firm's capability of acquiring demand information.

There is a literature on how upstream firms design contract to induce downstream firms' forecasting efforts. Fu and Zhu (2010) and Shin and Tunca (2010) investigate contracts employed by an upstream firm to induce the proper forecasting accuracy decision(s) of the downstream firm(s) and whether supply chain coordination is achievable under these contracts. Taylor and Xiao (2009) consider how return and rebate contracts properly induce the downstream firm to forecast and then compare the performances of these two types of contracts. These papers discuss the incentives of acquiring information where contracts are offered or negotiated before the forecasting accuracy is determined. Our paper, however, studies the impact of information status transparency where the contracts are designed after the information acquisition process.

There are studies that investigate information acquisition in conjunction with strategic disclosure in a vertical channel. Matthews and Postlewaite (1985) and Shavell (1994) study the incentives of a seller to acquire the product quality information and to disclose it to the consumer. Guo (2009) examines the impact of a downstream firm's information acquisition and strategic disclosure to an upstream firm under a wholesale price contract. We do not investigate information disclosure but do consider the optimal contract menu offered by the informationally inferior party, the manufacturer, to elicit information. Anand and Goyal (2009) consider information acquisition when there is information leakage (signaling) in a one-supplier-two-retailer supply chain. Kong et al. (2013) extend Anand and Goyal (2009) by considering revenue sharing contact and demonstrate that a revenue sharing scheme may prevent the supplier from leaking information. Li et al. (2013) study the reseller's information leakage and supplier encroachment in a dual channel. Our paper differs from these studies in both the situation modeled and the problems addressed.

The remainder of this paper is organized as follows. Section 2 sets up the model and provides a summary of main results. In §3, assuming a simplified "all or nothing" information structure, we solve for the equilibrium contract menu for the transparency and the nontransparency scenarios and identify conditions under which transparency benefits the retailer. Section 4 provides analyses for a more general "much or little" information structure. Section 5 concludes.

2. Model Setup and Main Results

A manufacturer supplies a product to a retailer. Both firms are risk neutral. The inverse demand function is $p = \theta - q$, where q is the retail quantity set by the retailer and p is the market clearing price. The intercept θ is a random variable, continuously distributed on $[l, u)$, $0 \le l < u \le \infty$, with mean $\bar{\theta}$, pdf $f(\cdot)$ and cdf $F(\cdot)$. Let $\bar{F}(\cdot) = 1 - F(\cdot)$. The retailer observes an unbiased signal Y about θ. The precision of the signal, defined as $\omega \triangleq 1/E[\mathrm{Var}[Y \mid \theta]]$, has two possible levels: ω equals ω_1 with probability t or ω_2 with probability $1-t$, where $\omega_1 > \omega_2$. The higher level of signal precision represents success of market research and the lower level, failure of market research. The retailer always observes ω. Transparency of information acquisition means that the manufacturer also learns ω, i.e., she knows whether it is at a high or a low precision level that the retailer has acquired the demand signal. The manufacturer never observes Y.

The probability t can be interpreted as the retailer's (or the hired consultant's) *information acquisition capability*: the larger is t, the more likely it is that the retailer will be successful in acquiring high-quality demand information (e.g., Jansen 2008, Guo 2009). The information acquisition capability t and the signal precision ω describe two very different aspects of market research.

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Whereas t describes how likely the retailer becomes informed at a high precision level, ω describes how precise his acquired information turns out to be.

We assume that the manufacturer uses a menu of quantity/payment bundle contracts (i.e., a schedule of quantity-price combinations) to extract supply chain surplus. Under symmetric information, a quantity/payment bundle contract can coordinate the supply chain and allow the manufacturer to extract all the supply chain profit. Under asymmetric information, a menu of quantity/payment bundle contracts is an optimal (to the manufacturer) form of incentive contract in screening models and can be interpreted as a nonlinear pricing contract (e.g., Tirole 1988, Corbett et al. 2004). We also assume that the retailer has a reservation profit independent of his information, which we normalize to zero. This is an assumption often made in mechanism design literature (e.g., Taylor and Xiao 2009). Recently, however, Oh and Özer (2013) relax this assumption and develop an incentive contract when the retailer's reservation profit endogenously depends on his private information.

In the (non)transparency scenario, the sequence of events is as follows:

1. The retailer observes a signal Y of the market potential θ. The signal has high precision, $\omega = \omega_1$, with probability t, or low precision, $\omega = \omega_2$, with probability $1 - t$. The retailer's realized signal precision ω is (*un*)*observable* to the manufacturer.
2. The manufacturer offers a quantity/payment contract menu.
3. The retailer chooses a contract from the contract menu.
4. Based on the quantity in the contract that he has chosen, the retailer decides his selling quantity.
5. The market clearing price realizes.

In step 3 of either scenario, the retailer has the freedom to leave the contract menu on the table and pursue his reservation profit. In that case, the manufacturer receives zero profit.

Summary of Main Results. We first analyze the case of "all or nothing," characterized by $\omega_1 = \infty$ and $\omega_2 = 0$. In this simplified situation, the retailer is perfectly informed (observes the exactly value of θ) with probability t or not informed at all with probability $1 - t$; that is, success of market research means that the retailer learns *all* about θ, and failure of market research means that he learns *nothing* about θ. This simplification allows us to derive analytical results neatly. By solving the transparency and the nontransparency scenarios and comparing firms' profits, we assess the impact of information acquisition transparency to individual firms in the supply chain. Not surprisingly, transparency always benefits the manufacturer since better information enables the manufacturer to fine-tune the contract menu to capture more profits. To the retailer, the downside of transparency is that he earns zero profit when he is uninformed. The upside is that transparency increases the contract quantity in the low demand market and, by so doing, forces the manufacturer to cede more information rent to the retailer in the medium to high demand market (so as to prevent the medium and high types from mimicking the low types). The trade-off depends on two key factors: the market variability and the retailer's information acquisition capability. We find that information acquisition transparency benefits the retailer if his information acquisition capability is less than stellar and the market variability is intermediate.

We then analyze the general case of "much or little," characterized by $0 < \omega_2 < \omega_1 < \infty$, where success of market research means that the retailer learns *much*, but less than everything, about θ, and failure of market research means that he learns *little*, but more than nothing, about θ. We demonstrate that impacts of transparency are qualitatively the same as those in the "all or nothing" case; in other words, the primary insights are robust and are not driven by the simplifying assumption of $\omega_1 = \infty$ and $\omega_2 = 0$.

That the retailer may benefit by disclosing his information status is somewhat nonintuitive. Because keeping his information status private seems to preserve the retailer's informational advantage, one might think that it would hurt the retailer to lose this advantage by exposing his information acquisition process to the manufacturer, especially when the latter is in a dominant market position to offer a quantity/payment bundle contract menu on a take-it-or-leave it basis. However, a more careful examination and a closer observation is called for.

To the manufacturer, the retailer's acquisition of demand information has two layers of knowledge. The first layer is that the attempt to acquire information may or may not be successful. The second layer is that, if the retailer has successfully acquired demand information, the market potential that he has forecasted may be high, medium, or low. Metaphorically speaking, one level of information is whether or not the retailer has a "secret," and the second level of information is what that secret is if the retailer does have a secret. Our result suggests that the retailer should treat the two layers of information differently when it comes to disclosure. The retailer should always keep the second layer knowledge (is the forecasted demand high, medium, or low?) from the manufacturer, for otherwise the manufacturer would offer a contract that will leave the retailer with only his reservation profit. However, it may serve the retailer well to make transparent whether or not he has actually acquired useful demand information (is the demand forecast accurate or not accurate?). Disclosure of information status is a mid-ground between strict confidentiality

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and no confidentiality. We show that it may be beneficial for the retailer to enter this mid-ground via a policy of partial confidentiality. In fact, this policy of partial confidentiality can significantly increase the retailer's profit by recovering some benefits that would be foregone under strict confidentiality.

When signing the confidentiality agreement with a market research consultancy, the client firm may do better under certain conditions to exclude the information status from the terms of agreement. Such exclusion means that the consultant is free to convey the information status to the manufacturer immediately after he learns it. Yet this does not enforce transparency of information status because an agreement of partial confidentiality allows, but does not require, the consultant to always disclose information status. Should the consultancy chooses to adhere to strict confidentiality on its own accord, the information status remains nontransparent and the retailer's profit remains the same. What partial confidentiality does imply is that the client firm obtains higher average profits over the long run if the consultant, inadvertently or purposefully, reveals the information status to the firm's supplier after completing market research projects.

3. Analyses for "All or Nothing"

We refer to the retailer as an informed retailer when he observes (a perfect signal of) θ or an uninformed retailer otherwise. Because θ is the retailer's private knowledge, we refer to it as the retailer's type. When there is no ambiguity, we also use θ to denote an arbitrary realization of the random variable θ. Under transparency, if the retailer is informed, the manufacturer knows so and her belief about the retailer's type θ follows the distribution $f(\cdot)$, and accordingly, she offers a contract menu $\{q^{tr}(\theta), T^{tr}(\theta)\colon \theta \in [l, u)\}$, i.e., quantity $q^{tr}(\theta)$ to be delivered for payment $T^{tr}(\theta)$, where the superscript "*tr*" stands for *tr*ansparency; if the retailer is uninformed, the manufacturer knows so and offers a single choice $\{q_o^{tr}, T_o^{tr}\}$.

Under nontransparency, the manufacturer does not know whether the retailer is informed or uninformed of θ. When the retailer is uninformed, for any quantity decision q, his expected revenue is $(\bar{\theta}-q)q$, which equals his revenue when he is informed and is of type $\theta=\bar{\theta}$. Therefore, an uninformed retailer would behave as if he is informed and has type $\theta=\bar{\theta}$. Under the belief that the retailer's type has a probability mass $1-t$ at $\theta=\bar{\theta}$ plus the distribution $f(\cdot)$ over $[l, u)$ which is scaled down to a total probability of t, the manufacturer offers $\{q^{nt}(\theta), T^{nt}(\theta)\colon \theta \in [l, u)\}$, where the superscript "*nt*" stands for *n*on*t*ransparency.

3.1. Transparency Scenario

If the retailer remains uninformed due to failure of market research, the manufacturer knows so and offers $(q_o^{tr}, T_o^{tr}) = (\bar{\theta}/2, \bar{\theta}^2/4)$. There is no information asymmetry in this case since neither firm knows θ. This contract maximizes the supply chain's profit, allocates all surplus to the manufacturer, and leaves zero information rent to the retailer.

If the retailer becomes informed of θ after success of market research, the manufacturer knows so. There is information asymmetry in this case because θ is known only to the retailer. To the manufacturer, θ follows distribution $f(\cdot)$, and accordingly she chooses a supply contract menu $\{q(\theta), T(\theta)\colon \theta \in [l, u)\}$ to maximize her profit by solving

$$\begin{aligned} \max_{q()\ge 0,\, T()\ge 0} \quad & \int_l^u T(\theta) f(\theta)\, d\theta \\ \text{s.t.} \quad & [\theta - q(\theta)]q(\theta) - T(\theta) \\ & \quad = \max_{\theta'} [\theta - q(\theta')]q(\theta') - T(\theta'), \\ & [\theta - q(\theta)]q(\theta) - T(\theta) \ge 0, \end{aligned} \tag{1}$$

where the constraints are of incentive compatibility and individual rationality, respectively. By the revelation principle, it is sufficient for the manufacturer to use an incentive-compatible contract menu (Myerson 1979) such that a type θ retailer would choose $(q(\theta), T(\theta))$. By Milgrom and Segal (2002), the incentive compatibility constraint is equivalent to $[\theta - q(\theta)]q(\theta) - T(\theta) = \int_l^\theta q(x)\, dx$. This implies that an informed retailer's information rent is given by $\int_l^\theta q(x)\, dx$.

LEMMA 1. *Problem* (1) *is equivalent to*

$$\begin{aligned} \max_{q()\ge 0} \quad & \int_l^u [2g(\theta) - q(\theta)] q(\theta) f(\theta)\, d\theta \\ \text{s.t.} \quad & q(\theta) \text{ is increasing in } \theta, \end{aligned} \tag{2}$$

where

$$g(\theta) \triangleq \frac{1}{2}\left[\theta - \frac{\bar{F}(\theta)}{f(\theta)}\right]. \tag{3}$$

Let $g^+(\theta) \triangleq \max(g(\theta), 0)$. Clearly, $q(\theta) = g^+(\theta)$ maximizes the term inside the integral. To ensure that $q(\theta)$ is increasing, we require that $g(\theta)$ is increasing in θ. This condition will hold if $f(\cdot)$ has increasing failure rate (IFR), i.e., if $f(\theta)/\bar{F}(\theta)$ increases in θ. We assume IFR on the market potential θ henceforth. IFR is a standard assumption in the contract design literature (Tirole 1988), which is satisfied by the uniform, the Weibull, and the (truncated) normal distributions, the three most often used distributions in the literature to describe random demands. Hence, the manufacturer's optimal contract menu $\{q^{tr}(\theta), T^{tr}(\theta)\colon \theta \in [l, u)\}$, when she knows that the retailer is informed, is given by

$$q^{tr}(\theta) = g^+(\theta), \tag{4}$$

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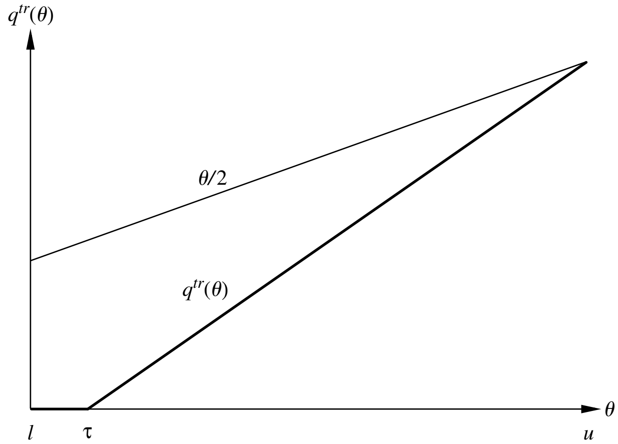
Figure 1 **Contract Quantity Menu Under Transparency When Retailer Is Informed**



Note. The market potential θ is uniformly distributed on $[1, 2.25]$.

and

$$T^{tr}(\theta) = [\theta - g^+(\theta)]g^+(\theta) - \int_l^\theta g^+(\theta)\, d\theta.$$

Since $g(\cdot)$ is increasing, $q^{tr}(\theta) = g^+(\theta) > 0$ for θ above a certain threshold $\tau \in [l, u)$. If $\tau > l$, there is a segment of low demand market, $\theta \leq \tau$, that is ignored by the manufacturer and not served by the supply chain. One would expect, in most cases, that the threshold τ is below the mean demand intercept $\bar\theta$ such that medium to high demand market is served. We assume that $g(\theta) > 0$ for $\theta > \bar\theta$.

Figure 1 shows the contract quantity $q^{tr}(\theta)$ for a uniformly distributed θ. Note that $\theta/2$ is the quantity that the manufacturer would offer if she knew θ, which would maximize the channel profit but leave zero profit to the retailer. Since she does not know the exact type θ of the retailer, there is a downward quantity distortion in the amount of $\bar F(\theta)/(2f(\theta))$. The distortion decreases with θ and vanishes as θ approaches the highest demand level u. This agrees with the well-known result from screening models that the highest type takes an ex post efficient action (e.g., Mas-Colell et al. 1995).

When uninformed, the retailer's profit (information rent) is zero. When informed at θ, the retailer's information rent is

$$\int_l^\theta q^{tr}(x)\, dx = \int_l^\theta g^+(x)\, dx.$$

Note that the information rent is increasing in the retailer type θ. The retailer's ex ante payoff in the transparency scenario is

$$\pi_R^{tr} = t\int_l^u \left(\int_l^\theta g^+(x)\, dx\right) f(\theta)\, d\theta = t\int_l^u g^+(\theta)\bar F(\theta)\, d\theta. \quad (5)$$

3.2. Nontransparency Scenario

To the manufacturer, nontransparency prevents her from knowing the information status of the retailer, effectively adding a probability mass, $1-t$, at $\theta = \bar\theta$, and scaling down the distribution, $f(\cdot)$, to a total probability of t. Note that the resulting distribution no longer has the IFR property even when $f(\cdot)$ itself is IFR.

The manufacturer's contract design problem can be written as

$$\begin{aligned} \max_{q()\geq 0,\, T()\geq 0} \quad & t\int_l^u T(\theta)f(\theta)\, d\theta + (1-t)T(\bar\theta) \\ \text{s.t.} \quad & [\theta - q(\theta)]q(\theta) - T(\theta) \\ & \quad = \max_{\theta'}[\theta - q(\theta')]q(\theta') - T(\theta'), \\ & [\theta - q(\theta)]q(\theta) - T(\theta) \geq 0. \end{aligned} \quad (6)$$

Lemma 2. *Problem* (6) *is equivalent to*

$$\begin{aligned} \max_{q()\geq 0,\, q_o} \quad & t\int_l^u [2g(\theta) - q(\theta)]q(\theta)f(\theta)\, d\theta \\ & + (1-t)\left[(\bar\theta - q_o)q_o - \int_l^{\bar\theta} q(\theta)\, d\theta\right] \\ \text{s.t.} \quad & q(\theta) \text{ is increasing in } \theta, \quad q(\bar\theta) = q_o, \end{aligned} \quad (7)$$

where $g(\theta)$ *is defined in* (3) *and* $q_o \in [g(\bar\theta), \bar\theta/2]$.

The manufacturer's objective (7) can be rewritten as

$$\begin{aligned} & t\int_l^{\bar\theta} [2h_t(\theta) - q(\theta)]q(\theta)f(\theta)\, d\theta + (1-t)(\bar\theta - q_o)q_o \\ & \quad + t\int_{\bar\theta}^u [2g(\theta) - q(\theta)]q(\theta)f(\theta)\, d\theta, \end{aligned} \quad (8)$$

where

$$h_t(\theta) = g(\theta) - \frac{1-t}{2tf(\theta)}.$$

Let $h_t^+(\theta) = \max(h_t(\theta), 0)$. The term in the integral from l to $\bar\theta$ is maximized by $q(\theta) = h_t^+(\theta)$. However, we need to make sure that the quantity is increasing in θ. For this we require that $h_t^+(\theta)$ is increasing in $\theta \in [l, \bar\theta)$ for any given t. The lemma below shows that this condition is satisfied by the uniform, the Weibull, and the (truncated) normal distributions. The term inside the integral from $\bar\theta$ to u is maximized by setting $q(\theta)$ to $g(\theta)$. However, $q(\theta)$ needs to be increasing in $[\bar\theta, u]$ and this requires that $q(\theta) \geq q(\bar\theta) = q_o$, thus $q(\theta) = \max[q_o, g(\theta)]$ for $\theta \in (\bar\theta, u)$. Taken together, the manufacturer's optimal contract quantity menu takes on the following form:

$$q^{nt}(\theta) = \begin{cases} h_t^+(\theta) & \text{for } \theta \in [l, \bar\theta), \\ q_o & \text{for } \theta = \bar\theta, \\ \max[q_o, g(\theta)] & \text{for } \theta \in (\bar\theta, u]. \end{cases} \quad (9)$$

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Lemma 3. *$h_t^+(\theta)$ is increasing in $\theta \in [l, \bar{\theta})$ for any given t for the uniform distribution, the Weibull distribution, and the normal distribution truncated at the lower or both tails.*

To complete the specification of $q^{nt}(\theta)$, we just need to determine $q_o \in [g(\bar{\theta}), \bar{\theta}/2]$ that maximizes the manufacturer's payoff (8). Since (8) is the sum of three terms and the first term does not depend on q_o, the manufacturer essentially maximizes

$$(1-t)(\bar{\theta}-q_o)q_o + t\int_{\bar{\theta}}^{u}\{2g(\theta)-\max[q_o, g(\theta)]\} \cdot \max[q_o, g(\theta)]f(\theta)\,d\theta.$$

Let $b = b(q_o) \in [\bar{\theta}, u)$ be such that $g(b) = q_o$ (recall that $g(\theta)$ is increasing in θ). We write the above as

$$(1-t)(\bar{\theta}-q_o)q_o + t\int_{\bar{\theta}}^{b(q_o)}[2g(\theta)-q_o]q_o f(\theta)\,d\theta + t\int_{b(q_o)}^{u}[g(\theta)]^2 f(\theta)\,d\theta. \quad (10)$$

Note that $g(b(q_o)) = q_o$ by definition. The second derivative of (10) with respect to q_o is $-2(1-t)q_o - 2t\int_{\bar{\theta}}^{b(q_o)} f(\theta)\,d\theta < 0$, so this is a concave maximization problem. It has a unique solution in $[g(\bar{\theta}), \bar{\theta}/2]$, and the optimal q_o decreases with t. Setting the first derivative to zero, we get

$$(1-t)\left[\frac{\bar{\theta}}{2}-q_o\right] - t\int_{\bar{\theta}}^{b(q_o)}[q_o - g(\theta)]f(\theta)\,d\theta = 0.$$

This equation can also be written in terms of b by substituting $q_o = g(b)$,

$$(1-t)\left[\frac{\bar{\theta}}{2}-g(b)\right] - t\int_{\bar{\theta}}^{b}[g(b)-g(\theta)]f(\theta)\,d\theta = 0. \quad (11)$$

Lemma 4. *q_o and b decrease with t. As t goes to 0, q_o approaches $\bar{\theta}/2$. As t goes to 1, q_o approaches $q^{tr}(\bar{\theta})$.*

Proposition 1. *The manufacturer's optimal contract menu $\{q^{nt}(\theta), T^{nt}(\theta)\colon \theta \in [l, u)\}$ when he does not know whether the retailer is informed of θ, is given by*

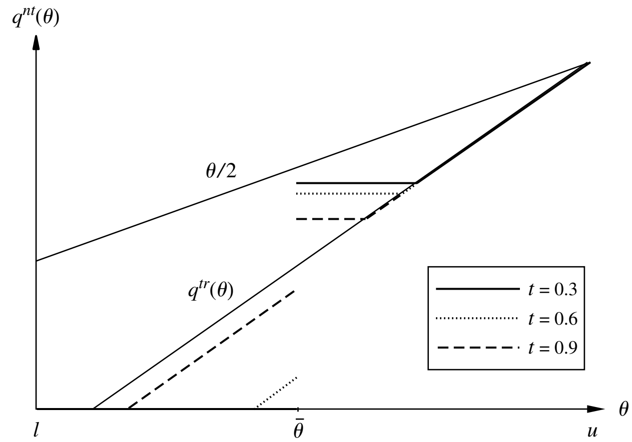
$$q^{nt}(\theta) = \begin{cases} h_t^+(\theta) & \text{for } \theta \in [l, \bar{\theta}), \\ g(b) & \text{for } \theta \in (\bar{\theta}, b], \\ g(\theta) & \text{for } \theta \in (b, u], \end{cases}$$

where b is determined from (11), and

$$T^{nt}(\theta) = [\theta - q^{nt}(\theta)]q^{nt}(\theta) - \int_l^{\theta} q^{nt}(\theta)\,d\theta.$$

Figure 2 shows the contract quantity $q^{nt}(\theta)$ for a uniformly distributed θ for different values of t. Since $h_t^+(\theta) \le g^+(\theta)$, we have $q^{nt}(\theta) \le q^{tr}(\theta)$ for $\theta < \bar{\theta}$, that is, nontransparency reduces the contract quantity for low range demand. We also note that $q^{nt}(\theta) > q^{tr}(\theta)$ for $\bar{\theta} \le \theta < b$ and $q^{nt}(\theta) = q^{tr}(\theta)$ for $\theta \ge b$, that is, nontransparency raises the contract quantity for medium range demand and leaves the contract quantity unchanged for high range demand. As the retailer's information acquisition capability t increases, $h_t^+(\theta)$ increases and q_o decreases, so the contract menus of the two scenarios approach each other.

Figure 2 **Contract Quantity Menu Under Nontransparency**



Note. The market potential θ is uniformly distributed on [1, 2.25].

The probability mass $1-t$ concentrated at $\theta = \bar{\theta}$ means greater importance of the mean demand market $\bar{\theta}$ and induces the manufacturer to set $q(\bar{\theta})$ higher than in the transparency scenario, $q^{nt}(\bar{\theta}) > q^{tr}(\bar{\theta})$. To obtain more profit from $\theta = \bar{\theta}$, he cedes to the retailer less information rent for $\theta \ge \bar{\theta}$ and also reduces the contract quantity in the low demand market, $q^{nt}(\bar{\theta}) < q^{tr}(\bar{\theta})$ for $\theta < \bar{\theta}$, to prevent the $\bar{\theta}$ type retailer from mimicking lower types. A consequence of the higher $q(\bar{\theta})$ is that it is now too costly for the manufacturer to differentiate the retailer types not much higher than $\bar{\theta}$, so she pools the retailer types between $\bar{\theta}$ and b.

When informed at $\theta \in [l, u)$, the retailer's information rent is

$$\int_l^{\theta} q^{nt}(x)\,dx.$$

When uninformed, the retailer's information rent is the same as when he is informed at $\theta = \bar{\theta}$,

$$\int_l^{\bar{\theta}} q^{nt}(\theta)\,d\theta = \int_l^{\bar{\theta}} h_t^+(\theta)\,d\theta.$$

Recall that an uninformed retailer in the transparency scenario always earns zero information rent. For t sufficiently small, $h_t^+(\theta) = 0$, so the uninformed retailer also earns zero profit in the nontransparency scenario if his information acquisition capability is low. For large t, however, the uninformed retailer may earn a positive profit.

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The retailer's ex ante payoff is the expected value:

$$\begin{aligned}\pi_R^{nt} &= t\int_l^u\left(\int_l^\theta q^{nt}(x)\,dx\right)f(\theta)\,d\theta+(1-t)\int_l^{\bar\theta} q^{nt}(\theta)\,d\theta\\ &= t\int_l^u q^{nt}(\theta)\bar F(\theta)\,d\theta+(1-t)\int_l^{\bar\theta} q^{nt}(\theta)\,d\theta\\ &= t\cdot\left\{\int_l^{\bar\theta} q^{nt}(\theta)\left[\bar F(\theta)+\frac{1-t}{t}\right]d\theta+\int_{\bar\theta}^u q^{nt}(\theta)\bar F(\theta)\,d\theta\right\}.\end{aligned}$$

Using (9), we write π_R^{nt} as

$$\begin{aligned}\pi_R^{nt} = t\cdot\bigg\{&\int_l^{\bar\theta} h_t^+(\theta)\left[\frac{1-t}{t}+\bar F(\theta)\right]d\theta\\ &+g(b)\int_{\bar\theta}^b \bar F(\theta)\,d\theta+\int_b^u g(\theta)\bar F(\theta)\,d\theta\bigg\}. \quad (12)\end{aligned}$$

3.3. Impact of Transparency

Not surprisingly, transparency helps the manufacturer.

Proposition 2. *Transparency of information acquisition always benefits the manufacturer.*

Intuitively, better information enables the manufacturer to fine-tune the contract menu to capture more profits.

Next, we will examine whether transparency can benefit the retailer and, if so, under what conditions. This will allow us to identify situations where there are benefits that are foregone because of strict confidentiality but can potentially be recovered by switching to a policy of partial confidentiality.

The retailer's payoff obviously depends on the retailer's information acquisition capability t. It also depends on the distribution function $F(\theta)$, which has support on $[l, u)$. To see the impact of a change in $F(\cdot)$, we consider a family of distributions that have the same "shape." This will help find key factors that determine the impact of transparency on the retailer.

Transformation of Variable. When the market potential θ has a finite support with a strictly positive lower bound, i.e., $0<l<u<\infty$, we define a standardized random variable z that is distributed over $[0,1]$ such that $\theta=l+s\cdot z$, where $s=u-l$ is the spread of θ. For example, if θ is uniformly distributed on $[l,u]$, then z is uniformly distributed on $[0,1]$. The random variable z has mean $\bar z$ that is related to the mean of θ by $\bar\theta=l+s\bar z$. Let $\varphi(\cdot)$ and $\Psi(\cdot)$ be the pdf and cdf of z, respectively, $\bar\Psi(z)=1-\Psi(z)$, and let

$$\gamma(z)=\frac{1}{2}\left(z-\frac{\bar\Psi(z)}{\varphi(z)}\right).$$

We have, for $\theta=l+sz$,

$$f(\theta)=\varphi(z)/s,\quad F(\theta)=\Psi(z),\quad \bar F(\theta)=\bar\Psi(z),$$
$$g(\theta)=s\left[\frac{l}{2s}+\gamma(z)\right],\quad h_t(\theta)=s\left[\frac{l}{2s}+\gamma(z)-\frac{1-t}{2t\varphi(z)}\right].$$

We can express b, the solution to (11), as $b=l+s\beta$ where β depends on t only and is determined from

$$(1-t)\left[\frac{\bar z}{2}-\gamma(\beta)\right]-t\int_{\bar z}^{\beta}[\gamma(\beta)-\gamma(z)]\varphi(z)\,dz=0. \quad (13)$$

We can then write (5) and (12), the retailer's payoffs in the transparency and the nontransparency scenarios, respectively, as

$$\pi_R^{tr}=ts^2\cdot\int_0^1\left[\frac{l}{2s}+\gamma(z)\right]^+\bar\Psi(z)\,dz,$$

and

$$\begin{aligned}\pi_R^{nt}=ts^2\cdot\bigg\{&\int_0^{\bar z}\left[\frac{l}{2s}+\gamma(z)-\frac{1-t}{2t\varphi(z)}\right]^+\left[\bar\Psi(z)+\frac{1-t}{t}\right]dz\\ &+\left[\frac{l}{2s}+\gamma(\beta)\right]\int_{\bar z}^{\beta}\bar\Psi(z)\,dz\\ &+\int_\beta^1\left[\frac{l}{2s}+\gamma(z)\right]\bar\Psi(z)\,dz\bigg\}.\end{aligned}$$

With this transformation, we have identified two key factors.

Proposition 3. *For $0<l<u<\infty$, whether the transparency of information acquisition benefits the retailer, i.e., whether $\pi_R^{tr}>\pi_R^{nt}$, depends on l/s and t. Specifically, for $t>0$, transparency benefits the retailer if and only if the following inequality holds:*

$$\begin{aligned}&\int_0^{\bar z}\left[\frac{l}{2s}+\gamma(z)\right]^+\bar\Psi(z)\,dz\\ &\quad>\int_0^{\bar z}\left[\frac{l}{2s}+\gamma(z)-\frac{1-t}{2t\varphi(z)}\right]^+\left[\bar\Psi(z)+\frac{1-t}{t}\right]dz\\ &\qquad+\int_{\bar z}^{\beta}[\gamma(\beta)-\gamma(z)]\bar\Psi(z)\,dz.\end{aligned}$$

The reciprocal of l/s is $s/l=(u-l)/l$, which bears resemblance to the coefficient of variation and can be thought of as measuring the market dispersion. The above proposition says that whether the retailer gains or loses by making his information acquisition transparent to the manufacturer is determined by two parameters, the market dispersion and the information acquisition capability.

Under the condition of Proposition 3, the retailer's disclosure of information status is a win-win solution for the supply chain, benefiting both the retailer and the manufacturer.

Corollary 1. *For $0<l<u<\infty$, transparency harms the retailer for sufficiently small s.*

The retailer has two layers of knowledge, his information status (whether I know) and the market potential when he is informed (what I know). The value of the second layer knowledge depends on the market

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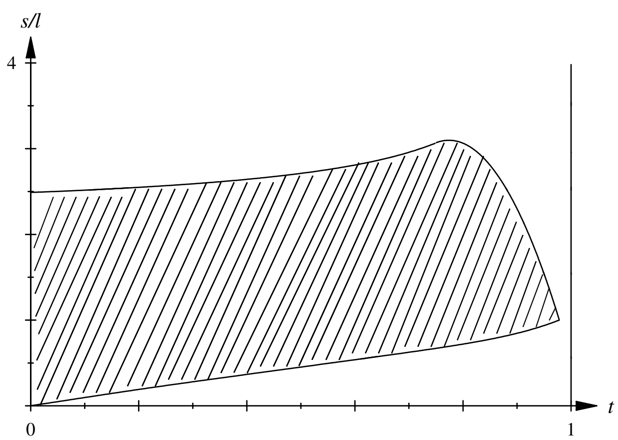
dispersion. If s is very small, the demand variability is small and thus the knowledge about θ has very little value. By the corollary, when the second layer knowledge carries little value, the first layer knowledge, relatively, will be an important source of informational advantage and it is better for the retailer to keep it to himself rather than disclosing it to the manufacturer.

Corollary 2. *For $0 < l < u < \infty$, transparency harms the retailer for sufficiently large s if $\bar{z}\varphi(\bar{z}) \le \bar{\Psi}(\bar{z})$.*

The condition $\bar{z}\varphi(\bar{z}) \le \bar{\Psi}(\bar{z})$ implies that $\gamma(z) < 0$ for $z < \bar{z}$. This condition is satisfied, for example, by the uniform distribution. Under this condition, when s is very large, $g^+(\theta) = s[l/(2s) + \gamma(z)]^+ = 0$ (implying $h_t^+(\theta) = 0$) for $\theta < \bar{\theta}$; namely, when the market dispersion is very large, the low demand market is ignored. We know that the manufacturer gets most of its profit from the high range demand market but has to pay some information rent to screen the high type retailer (large θ) from the low type retailer (small θ). When facing a market that has greater dispersion and thus offers greater potential payoff in the high range demand, the manufacturer concentrates exclusively on the high range demand market and ignores the relatively insignificant low range demand market. With the low demand market cut off in both scenarios, because transparency reduces the contract quantity for the high range demand (recall $q^{nt}(\theta) \ge q^{tr}(\theta)$ for $\theta > \bar{\theta}$), the retailer earns less information rent in the transparency scenario.

Figure 3 shows a diagram for uniformly distributed θ with the information acquisition capability t as the horizontal axis and the market dispersion s/l as the vertical axis. The shaded area is where the retailer earns more profit under transparency of information acquisition than under nontransparency. For the uniform distribution we can show analytically that, given any t, if $\pi_R^{tr} > \pi_R^{nt}$ at $s = s_1$ and s_2, then $\pi_R^{tr} > \pi_R^{nt}$ for all s between s_1 and s_2. The benefit of transparency to the retailer can be substantial. Numerical examples can be easily constructed in which transparency increases the retailer's payoff by more than 100%. We see that transparency is beneficial to the retailer only when the market dispersion is neither too large nor too small. This is consistent with Corollaries 1 and 2. We also see that transparency would harm the retailer if his information acquisition capability is very high. The reason is based on two facts: first, an uninformed retailer under transparency always earns zero information rent but under nontransparency earns a positive information rent that is larger for greater t; second, the contract menus, $q^{tr}(\theta)$ and $q^{nt}(\theta)$, are very close to each other when t is near one. For t close to one, a change from transparency to nontransparency gives the uninformed retailer a quantum leap in payoff but causes only a very small change in the payoff of the informed retailer, thus resulting in higher ex ante expected payoff for the retailer.

Figure 3 **Impact of Transparency on the Retailer When Market Potential Follows a Uniform Distribution**



Notes. The market potential θ is uniformly distributed on $[l, u]$. Market dispersion is s/l, where $s = u - l$.

To the retailer, the downside of information acquisition transparency is that he earns zero profit when he is uninformed. The upside is that transparency increases the contract quantity in the low demand market, $q^{tr}(\theta) > q^{nt}(\theta)$ for $\theta < \bar{\theta}$, and in so doing, forces the manufacturer to cede more information rent to the retailer in the medium to high demand market (in order to prevent the medium and high types from mimicking the low types). This is the main positive impact of transparency to the retailer. This impact is small when the market variation is so large that the manufacturer cares little about the low demand market. The impact is negligible when the market variation is very small, because the value of information is small and the information rent is little. The impact is marginal when the retailer's information acquisition capability t is so great that the two contract quantities, $q^{tr}(\theta)$ and $q^{nt}(\theta)$, are very close to each other.

The transformation in Proposition 3 makes sense only when the lower bound $l > 0$ and $u < \infty$ so that the market dispersion s/l is well defined. If the market potential θ has support on $[0, \infty)$, we use the coefficient of variation or a related parameter to measure the dispersion (the shape) of θ. We consider two such cases, the normal and the Weibull distributions. Figure 4 shows a diagram for normal-distributed θ with the coefficient of variation as the vertical axis. The shaded area is where transparency benefits the retailer. For the normal distributions we can show analytically that, given any t, if $\pi_R^{tr} > \pi_R^{nt}$ at $\sigma = \sigma_1$ and σ_2, then $\pi_R^{tr} > \pi_R^{nt}$ for all σ between σ_1 and σ_2.

If θ follows a Weibull distribution with probability density function, $f(\theta) = ak\theta^{k-1}e^{-a\theta^k}$, where a is a scale parameter and k is a shape parameter, the coefficient of variation depends on k only and is increasing in $1/k$.

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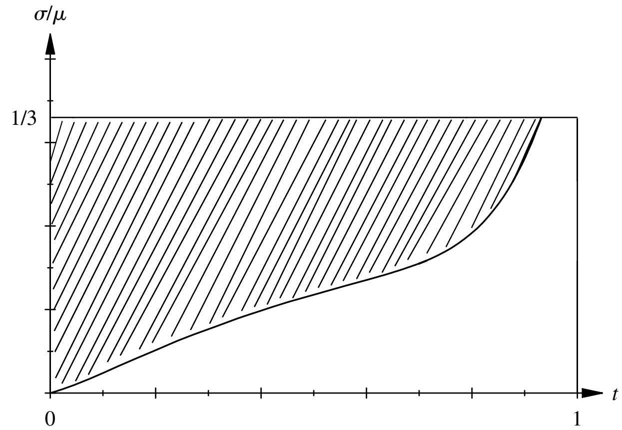
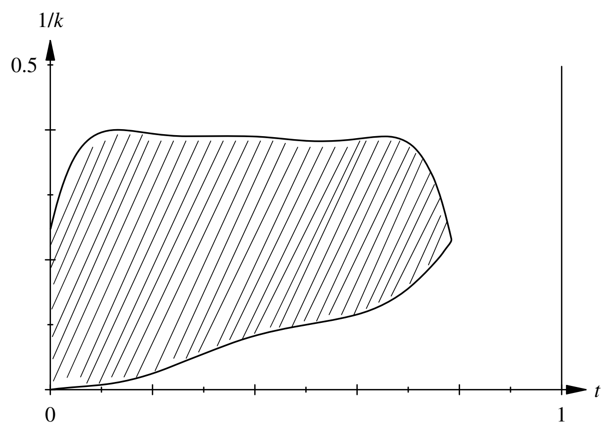
Figure 4 **Impact of Transparency on the Retailer When Market Potential Follows a Normal Distribution**



Notes. The market potential θ is normally distributed with $\mu = 30$. Coefficient of variation is σ/μ.

Figure 5 **Impact of Transparency on the Retailer When Market Potential Follows a Weibull Distribution**



Notes. The market potential θ follows a Weibull distribution with shape parameter k. Smaller k (i.e., greater $1/k$) implies larger coefficient of variation.

Figure 5 shows a diagram for Weibull-distributed θ with $1/k$ as the vertical axis. The shaded area is where transparency benefits the retailer. The same pattern emerges: transparency benefits the retailer if the market variability is intermediate and his chance of failure in information acquisition is not insignificant.

4. Analyses for "Much or Little"

In §3 we study the simplified case where the precision of the signal, $\omega = 1/E[\mathrm{Var}[Y \mid \theta]]$, is either infinite or zero, i.e., the retailer either knows all about θ ($\omega_1 = \infty$) or nothing at all ($\omega_2 = 0$). In this section we consider the general case where the precision ω equals ω_1 with probability t or ω_2 with probability $1-t$, $0 < \omega_2 < \omega_1 < \infty$. In this case, success of market research means that the retailer learns *much*, but less than everything, about θ, and failure of market research means that he learns *little*, but more than nothing, about θ. We will demonstrate that the results from the last section carry over qualitatively unchanged to this general case of "much or little." In other words, the primary insights are robust and are not driven by the simplifying assumption of "all or nothing."

We assume that the demand intercept θ follows a normal distribution with mean $\bar{\theta} = \mu$ and variance σ^2. The consultancy observes $Y = \theta + \xi$ and communicates this number to the retailer. The error term ξ is normally distributed with mean zero and variance v^2, where the error variance v^2 equals $v_1^2 = 1/\omega_1$ with probability t or $v_2^2 = 1/\omega_2$ with probability $1-t$. For fixed v, the conditional distribution of θ given Y is a normal distribution with mean $E_v[\theta \mid Y] = \alpha\mu + (1-\alpha)Y$ and variance $\alpha\sigma^2$, where $\alpha = v^2/(\sigma^2 + v^2)$. Note that $E_v[\theta \mid Y]$ is itself normally distributed, with mean μ and variance $\sigma^4/(\sigma^2 + v^2)$.

Transparency Scenario. In the transparency scenario, the manufacturer knows the standard deviation of the forecast error ξ, $v = v_1$ or v_2, but not the signal Y. Given a contract menu offered by the manufacturer, the retailer chooses a contract (q, T) from the menu to maximize his expected profit, $q(E_{v_i}[\theta \mid Y] - q) - T$, conditional on his observed signal Y. From the manufacturer's perspective, the retailer's characteristic (i.e., his type) is fully specified by $E_{v_i}[\theta \mid Y] \sim N(\mu, \sigma^4/(\sigma^2 + v_i^2))$. Note that the situation now resembles the transparency scenario for "all or nothing" of §3.1, except that the retailer's type was previously described by θ but is now by $Z_i = E_{v_i}(\theta \mid Y)$. Let $f_i(z)$ and $F_i(z)$ be the probability density and cumulative distribution of Z_i, respectively. Similar to §3.1, when $v = v_i$, $i = 1, 2$, the manufacturer's optimal contract quantity menu is

$$q_i^{tr}(z) = \frac{1}{2}\left[z - \frac{\bar{F}_i(z)}{f_i(z)}\right]^+, \tag{14}$$

and that the retailer's ex ante profit is

$$\pi^{tr} = t\int_0^\infty q_1^{tr}(z)\bar{F}_1(z)\,dz + (1-t)\int_0^\infty q_2^{tr}(z)\bar{F}_2(z)\,dz.$$

Nontransparency Scenario. In the nontransparency scenario, the manufacturer does not know whether $v = v_1$ or v_2. Given a contract menu, the retailer chooses a contract (q, T) to maximize $q(E_{v_i}(\theta \mid Y) - q) - T$ and his choice only depends on the value of $E_{v_i}(\theta \mid Y)$. In fact, for (v_1, Y_1) and (v_2, Y_2) such that $E_{v_1}[\theta \mid Y_1] = E_{v_2}[\theta \mid Y_2]$, the retailer would choose exactly the same (q, T) from the menu. Therefore, from the manufacturer's perspective, the retailer's characteristic (i.e., his type) is fully specified by $Z = E_v[\theta \mid Y]$, where v equals v_1 with probability t or v_2 with probability $1-t$. For any given t, the probability density and cumulative distribution of Z are, respectively,

$$f_t(z) = tf_1(z) + (1-t)f_2(z),$$
$$F_t(z) = tF_1(z) + (1-t)F_2(z).$$

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The manufacturer solves

$$\begin{aligned} &\max_{q()\geq 0,\, T()\geq 0} \int_0^\infty T(z) f_t(z)\, dz \\ &\quad \text{s.t.}\quad [z-q(z)]q(z)-T(z) \\ &\qquad\qquad = \max_{z'}\{[z-q(z')]q(z')-T(z')\}, \\ &\qquad\qquad [z-q(z)]q(z)-T(z)\geq 0. \end{aligned} \tag{15}$$

This problem is equivalent to

$$\begin{aligned} &\max_{q()\geq 0,\, T()\geq 0} \int_0^\infty [2g_t(z)-q(z)]q(z) f_t(z)\, dz \\ &\quad \text{s.t.}\quad q(z) \text{ is increasing in } z, \end{aligned} \tag{16}$$

where

$$g_t(z) \triangleq \frac{1}{2}\left[z - \frac{\bar{F}_t(z)}{f_t(z)}\right].$$

Let $g_t^+(z) \triangleq \max(g_t(z), 0)$. Clearly, $q(z) = g_t^+(z)$ maximizes the term inside the integral. This may look similar to (14), but the difference now is that $g_t^+(z)$ may not be a correct solution to (16) because it may not be increasing in z. The problem arises from the fact that $f_t(\cdot)$ may not be IFR even when $f_1(z)$ and $f_2(z)$, both being normal distributions, are IFR (Block et al. 2005). We remedy this problem by employing a technique well known in control theory (called ironing, based on the Pontryagin condition) to replace a critical segment of $g_t^+(z)$, $z\in[z_1, z_2]$, that is nonmonotonic, with a properly defined horizontal line, $q^{nt}(z) = q_o$. The manufacturer's optimal contract quantity menu is

$$q^{nt}(z) = \begin{cases} g_t^+(z) & \text{for } z < z_1, \\ q_o & \text{for } z_1 \leq z \leq z_2, \\ g_t^+(z) & \text{for } z > z_2, \end{cases}$$

where q_o, z_1 and z_2 (as functions of t) are uniquely determined by

$$\int_{z_1}^{z_2} [q_o - g_t^+(z)] f_t(z)\, dz = 0.$$

Figure 6 illustrates how this is done and a formal proof of this procedure is given in the online supplement (available at http://dx.doi.org/10.1287/msom.2014.0478). The retailer's ex ante profit is given by

$$\pi^{nt} = \int_0^\infty q^{nt}(z)\bar{F}_t(z)\, dz.$$

Impact of Transparency. First, we can show easily that transparency of information acquisition always benefits the manufacturer.

To understand the impact of transparency on the retailer, we numerically compare his profits between the transparency and nontransparency scenarios for a large set of parameter settings. We find that, for any given μ, v_1, and v_2, there is a continuous region of t and σ in which transparency benefits the retailer. The following two figures are representative of findings from our extensive numerical studies. The shaded area is where the retailer would benefit by making his information status transparent to the manufacturer.

In Figure 7, the forecast errors at the two precision levels differ substantially, yet still by less than one magnitude. In Figure 8, the forecast errors differ by more than one magnitude. Note that Figure 8 is almost the same as Figure 4, as one would expect. In all situations, a sufficient condition for transparency to benefit the retailer is that the demand variability is intermediate and the information acquisition capability is less than stellar. The impact of transparency on the retailer's profit depends on the difference of the two precision levels, from up to 10% in the setting of Figure 7 ($v_1 = 2$, $v_2 = 10$), to up to 30% for $v_1 = 2$ and $v_2 = 30$, to up to more than 100% in the setting of Figure 8 ($v_1 = 1$, $v_2 = 100$).

Figure 6 Illustration of the "Ironing" Technique

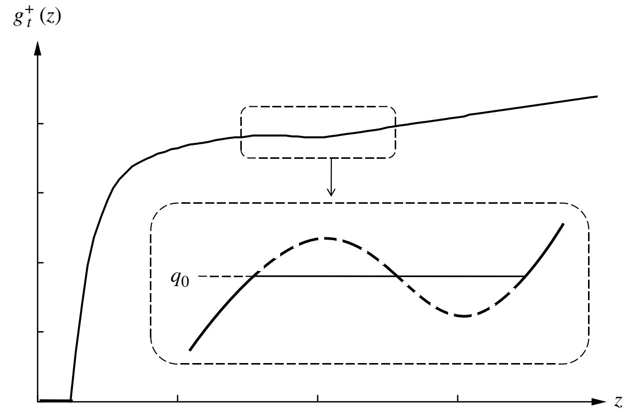
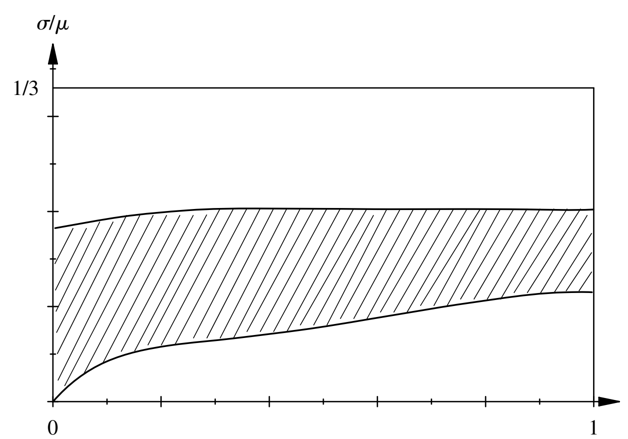


Figure 7 Impact of Transparency on the Retailer When Signals Are Imperfect



Notes. The market potential θ is normally distributed with $\mu = 30$. Coefficient of variation is σ/μ. The standard deviations of forecast errors are $v_1 = 2$ and $v_2 = 10$.

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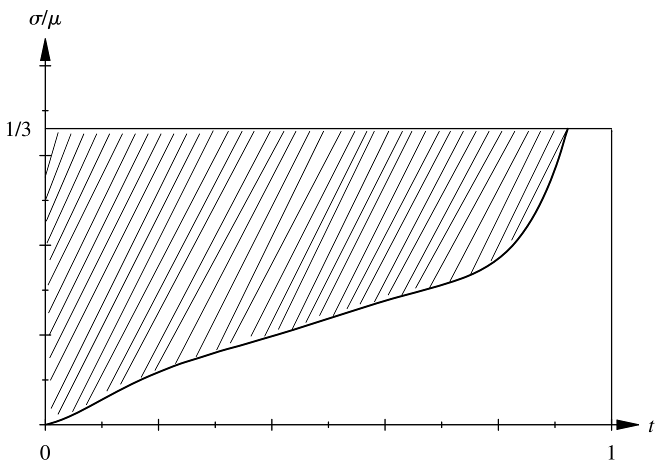
Figure 8 Impact of Transparency on the Retailer When Signals Are Imperfect



Notes. The market potential θ is normally distributed with $\mu = 30$. Coefficient of variation is σ/μ. The standard deviations of forecast errors are $v_1 = 1$ and $v_2 = 100$.

Value of Consulting Services. An implicit assumption in the story of this paper is that the retailer always hires a consultant to acquire information, $Y = \theta + \xi$, about the uncertain demand intercept, θ, for otherwise he would be completely uninformed and would earn zero information rent. As a consultant is characterized by three parameters (t, v_1, v_2), where $v_1^2(v_2^2)$ is the error variance at high (low) precision, $v_1 < v_2$, and t is the probability of the high precision, he has an ex ante expected error variance equal to $E[\xi^2] = tv_1^2 + (1-t)v_2^2$. A question of interest to the retailer is what type of consultants would help him the most. Specifically, of two consultants having the same expected error variance, which one, if hired, would provide a market research service that will result in more expected profits for the retailer? To answer this question, we performed three sets of sensitivity analyses, all done for fairly high levels of t.

First, we fixed t and kept $tv_1^2 + (1-t)v_2^2$ constant, and numerically evaluated $\pi \triangleq \max(\pi^{tr}, \pi^{nt})$, which is the retailer's profit at the optimal transparency level, for varying values of v_1 and v_2. We found that π decreases with v_1 (i.e., increases with v_2). In other words, the retailer prefers the consultant whose two precision levels are further apart, i.e., very small (big) error at the high (low) precision level—an inconsistent consultant, over a consultant whose performance is consistently mediocre.

Second, we fixed v_1 and kept $tv_1^2 + (1-t)v_2^2 = v_1^2 + (1-t)(v_2^2 - v_1^2)$ constant, and numerically evaluated π for varying values of t and v_2. A clear pattern emerged: π increases with t (i.e., increases with v_2). That is, the retailer prefers the consultant who has a greater chance of success but learns nearly nothing in case of failure, over a consultant who has a smaller chance of success but learns just a little in case of failure.

Third, we fixed v_2 and kept $tv_1^2 + (1-t)v_2^2 = v_2^2 - t(v_2^2 - v_1^2)$ constant, and numerically evaluated π for varying values of t and v_1. Again a clear pattern emerged: π increases with t (i.e., increases with v_1). That is, the retailer prefers the consultant who has a greater chance of success but learns less than perfect in case of success, over a consultant who has a somewhat smaller chance of success but learns nearly perfect in case of success.

These findings provide some guidelines for selecting a consultant.

5. Concluding Remarks

We have found foregone benefits in strict confidentiality that can potentially be recovered by switching to a policy of partial confidentiality in the context of commissioned market research. Strict confidentiality required by a client firm on a hired market research consultant can be self-defeating in that the client may actually be better off with a less restrictive, partial confidentiality, whereby the firm's information status may be exposed to the supplier through the mouth of the consultant. It appears to be a conventional wisdom, practiced by many firms in a weak market position, to keep all private information to themselves lest they lose informational advantage. Our result shows that this standard practice, sensible as it may seem, is not always wise.

A firm hires a consultancy to acquire demand information. The outcome of information acquisition may turn out to be either successful such that the firm becomes informed of the market demand, or unsuccessful such that it remains uninformed. The firm's information status about the market demand, informed or uninformed, is contingent on the outcome of the information acquisition process, which is learned by the firm through the hired consultant after the outcome becomes clear. Firms usually forbid consultants to disclose anything about the information acquisition, including the information status, to other companies, believing that greater informational advantage can only be to their own benefits. Meanwhile, consultancies follow a confidentiality agreement signed with the client firm.

However, should the firm indeed care so much about confidentiality? Will it be beneficial if the firm's information status is known to its partners or any other firms? This is an unaddressed issue in the existing literature. We investigate this issue in the context of a two-tier supply chain. We characterize conditions under which a retailer benefits from making his information status transparent to the manufacturer. Our result suggests that, when it comes to disclosure, the retailer should treat the information status and the information content differently. Facing a manufacturer of dominant

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position, the retailer suffers a loss by disclosing the content of his information, but he may enjoy a gain by disclosing his information status. Intuitively, under the right circumstances, the retailer would want the manufacturer to know that he has a secret because he could extract value if he were able to pique the manufacturer's curiosity.

We have focused on quantity-price bundle contracts. This is an optimal form of contracting for the manufacturer. We can show that the impact of transparency is similar for a two-part tariff (two-part linear pricing) contract menu. Our model has also assumed a continuous distribution with IFR property for the uncertain market potential. Similar results can be obtained for the case of binary-state demand distributions where the retailer observes an *imperfect* demand signal with two possible precision levels.

One line for potential future research is to consider more complex supply chain structures. These include multiple retailers supplied by one manufacturer, multiple manufacturers supplying one retailer, or supply chains competing with one another.

Supplemental Material

Supplemental material to this paper is available at http://dx.doi.org/10.1287/msom.2014.0478.

Acknowledgments

The authors thank the editor-in-chief, the associate editor, and two reviewers for their helpful comments and constructive suggestions. Tian Li's research is supported in part by the National Natural Science Foundation of China [Grant 71301050] and the Shanghai Pujiang Program [Grant 13PJC022]. Hongtao Zhang's research is supported in part by the Research Grants Council of Hong Kong General Research Fund [Grants 622107 and 644009].

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