Slotting allowances and information gathering

by

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***Abstract*:** This paper considers a mechanism design problem in which a retailer motivates a manufacturer to gather information concerning the demand for its new product. The information will be of value to the retailer, in deciding whether to allocate limited shelf space for the new product. The model reveals that if the retailer cannot observe whether the manufacturer has gathered information, then to motivate the manufacturer to do so, the retailer will charge slotting allowances and distort the quantity away from its full information levels. Slotting allowances may increase or decrease social welfare, depending on the parameters of the model.

Keywords: mechanism design, asymmetric information, antitrust policy, productive information gathering

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1. Introduction

Slotting allowances are fixed, up-front payments that manufacturers make to retailers for reserving shelf space. Slotting allowances are very common in the retail grocery industry. For example, the Federal Trade Commission (2003) found that manufacturers paid slotting allowances for introducing bread, hot doges, ice cream, pasta and salad dressing. Moreover, introducing a new grocery product requires, on average, paying $1.5 - $2 million in slotting allowances.

Slotting allowances challenge conventional economic logic in that the seller is the one paying the buyer. Consequently, this practice led to attempts by antitrust authorities to assess their potential effects on competition, consumers and welfare.[1] On one hand, slotting allowances are suspected of excluding financially constrained manufacturers who cannot finance high upfront payments to retailers. Also, they may have the anti-competitive effect of enabling retailers to reduce downstream competition. At the same time, slotting allowances may have the welfare-enhancing property of enabling retailers to efficiently allocate scarce shelf space between products.

The aim of this paper is to provide a new explanation for the use of slotting allowances, and to evaluate their effect on welfare. I consider a mechanism design problem in which a retailer needs to motivate a manufacturer to gather costly information concerning the demand for its new product, and to reveal this information to the retailer. The model reveals that the equilibrium mechanism includes slotting allowances. However, the mechanism also forces the retailer to distort its quantity away from its first best level, either downwards or upwards, depending on the actual realization of the demand.

This paper considers a model with the following properties. A monopolistic retailer, R, offers a contract to a manufacturer, M, that produces a new product whose demand is initially unknown to both M and R. M and R believe that the demand for the new product is drawn from either a high (H) or low (L) distribution functions over the same support, where H result in a higher expected profit than L. From R's viewpoint, it is profitable to place the new product on the shelf only if its distribution is H. Otherwise, R prefers to use its scarce shelf space for offering an old product whose demand is common knowledge. M can perform a costly test in the form of market research that reveals to M the state (that is, whether the actual demand for the new product will be drawn from distribution H or L). For example, the market research may involve trying out the new product on test groups, or surveying potential customers by means of telemarketing or questionnaires at selling points. R however cannot perform the test. Nor can R observe the results of the test. Intuitively, market research requires an expensive gathering of marketing data and accurate data analysis. Even though M

[1] See for example the report by the Federal Trade Commission (2001) and the Israeli Antitrust Authority (2003).

can always claim to have carried out such research and exhibit marketing data, R may not be able to assess whether the data is a result of a comprehensive effort by M.

R can learn the actual demand ex-post by placing the product on the shelf and observing consumers' purchasing decisions, but at the expense of not selling the old product. R cannot know ex-post, after observing the realization of demand for the new product, whether M has performed the test or not, because each realization of demand can be drawn from each of the two distribution functions. I assume also that the realization of the demand is not verifiable and therefore cannot be contracted on.

This setting raises a conflict of interests between R and M. For R, performing the test may be more profitable than the alternative option of trying the new product on the shelf, because the profit from not selling the old product that R forgoes when placing the new product on the shelf may be higher than the cost of performing the test. M, however, does not forgo the profit from not selling the old product, and therefore always prefers not to test the product by means of market research, preferring rather to place it on the shelf and observe the consumers' actual purchasing decisions. Moreover, even if M performs the test and finds that the demand will be drawn from distribution L, there will always be the incentive to falsely represent the state as H. R thus faces a problem of moral hazard and adverse selection, and needs to write a mechanism that motivates M to both perform the test, and truthfully reveal its outcome.

I consider a mechanism in which R offers a menu that includes a set of quantities and monetary transfers from R to M, which can be either positive (such as franchise fees) or negative (such as slotting allowances). R commits that if M accepts the contract, R will place the new product on the shelf, and after observing the demand, R will choose a line (namely, a quantity and a transfer), from the menu. R needs to design a mechanism that induces M to accept the contract only after testing its product and observing that the state is H.

The model reveals that under full information, where R can observe whether M has tested its product (or when M knows the demand for its product without performing market research), R can implement the vertical integration outcome without the need for slotting allowances. However, under asymmetric information, where R cannot observe whether M has performed the test, R cannot implement the vertical integration outcome. The distortion in the equilibrium outcome, in comparison with the vertical integration outcome, depends on the gap between the cumulative distribution functions in the two states. For the case where the cumulative distribution function in state H is lower than in state L, the total payment is negative (i.e., a payment from M to R) if the demand is low, increasing with the realization of demand and positive (i.e., a payment from R to M) if the demand is high. Moreover, the menu specifies a quantity below the full information quantity. Intuitively, R sets a "penalty" for low realizations of demand because they are more likely to be drawn in state L, and a "reward" otherwise. After placing the product on the shelf and observing a high realization of demand,

however, R will have an incentive to choose a line from the menu that corresponds to a low demand in order to benefit from the associated payment from M. To prevent this, R will need to distort the quantity downwards. In other words, R distorts the transfer to "punish" M for realizations of demand that are less likely in state H, and distorts the quantity in order to prevent R from ex-post punishing M unnecessarily. Following the same intuition, if for some realizations of demand the cumulative distribution function in state H is higher than in state L, then the total payment is decreasing with the demand, while the equilibrium quantity is distorted upwards. Consequently, the mechanism may involve downwards distortion for some realizations of demand while upwards for others.

The model also reveals that for the case where the cumulative distribution function in state H is lower than in state L, R can implement the optimal mechanism by asking for upfront slotting allowances, and offering a positive payment to M which is increasing with the quantity that R buys.

This result provides a new explanation for why retailers charge slotting allowances. Indeed, there is some anecdotal evidence for a link between slotting allowances and market research. The report by the Federal Trade Commission (2001), based on the testimonies of selected managers, says that "Some participants stated that a manufacturer's willingness to pay an up-front slotting fee is a tangible, credible statement of confidence … since the manufacturer is the party that has had the best opportunity to study the potential of the new product – for example, as a result of research and test marketing" (p. 13). In an empirical examination of the link between market research and slotting allowances, Sudhir and Rao (2004) find that for manufacturers that do not have a reputation for conducting and revealing credible market research, slotting allowances serve to complement market research. Sudhir and Rao interpret their results through signaling theory: market research indicates that the manufacturer has private information, which it signals by means of slotting allowances. My paper shows that the causality between market research and slotting allowances may be reversed. That is, it is not that market research motivates manufacturers to signal their private information through slotting allowances, but that slotting allowances may motivate manufacturers to perform market research.

As far as social welfare is concerned, my paper reveals that if antitrust authorities prohibit R from charging a negative transfer, R cannot motivate M to test its product and will either sell the new product without testing it or sell the old product. A slotting allowance on one hand increases social welfare because it enables R to allocate its scarce shelf space to the most valuable product, but at the same time may result in a downward distortion of the equilibrium quantity. Numerical simulation shows that slotting allowances may increase or decrease social welfare, depending on the cost of the test and the profit from the old product.

Previous economic literature has provided several explanations for the existence of slotting allowances. Shaffer (1991), Kim and Staelin (1991), Shaffer (2005), Rey, Miklós-Thal and Vergé (2006), Innes and Hamilton (2006), Kuksov and Pazgal (2007) and Marx and Shaffer (2007) consider them to be the result of retail competition. Marx and Shaffer (2004) and Inderst (2005) show that a retailer may limit its shelf space and charge slotting allowances to increase the competition among suppliers for shelf space. Sullivan (1997) shows that slotting allowances emerge as part of an equilibrium clearance condition in a market with a set of competing manufacturers and retailers.

Another explanation for slotting allowances, which is closely related to my paper, is that they serve to convey manufacturers' private information regarding demand. Chu (1992) shows that a retailer may charge a slotting allowance to screen high demand manufacturers from low demand manufacturers. Lariviere and Padmanabhan (1997) show that a manufacturer will signal high demand through slotting allowances. Desai (2000) focuses on the tradeoff between signaling quality to retailers through slotting allowances or advertising. There are two main differences between the above literature and my paper. First, these papers assume that the manufacturer already knows the demand, thus ignoring the question of why manufacturers may perform a costly test to obtain this information. Second, Lariviere and Padmanabhan (1997) and Desai (2000) assume that the manufacturer has the bargaining power to set the slotting allowance and the wholesale price, and Chu (1992) assumes that the manufacturer has the bargaining power to set the wholesale price alone. In contrast, my paper focuses on the case where the retailer has full bargaining power to offer a non-linear tariff that may includes a payment from M to R. The results of my model show that these two differences are crucial: if the retailer has all the bargaining power, and the manufacturer knows the true demand without testing the product, then the slotting allowance will not emerge in equilibrium. Therefore, this paper contributes to the above literature by explaining why retailers use slotting allowances in cases when they have significant bargaining power and manufacturers need to costly gather information.

On the empirical side, Bloom, Gundlach and Cannon (2000) find that, by and large, managers believe that slotting allowances emerge because of retailers' growing market power. The Federal Trade Commission (2003) has conducted a case study analysis and found that slotting allowances may signal a manufacturer's beliefs about demand, and serve other purposes such as covering the retailer's operational cost. As stated above, the Federal Trade Commission (2001) and Sudhir and Rao (2004) provide some support for the link between slotting allowances and market research.

My paper also relates to the literature on information gathering. Crémer and Khalil (1992), Lewis and Sappington (1997), Crémer, Khalil and Rochet (1998a,b), Szalay (2006) and Shin (2008) consider a principal-agent problem when an agent can costly gather

information regarding a project.[2] Finkle (2005) and Nosal (2006) consider the case when the principal can privately gather information and convey it to an agent. My paper differs from the above literature in that here the agent (namely, M) needs to gather information while the principal (namely, R) privately observes some signal (i.e., the realization of demand) for the information gathered by the agent.

Finally, this paper is also related to Eliaz and Spiegler (2007), Eliaz and Spiegler (forthcoming) and Eliaz and Spiegler (forthcoming) that have considered mechanism deign problems when players have different priors over potential states. They show that contracts are essentially "bets" among players over the potential outcomes. Following their terminology, it is possible to interpret the equilibrium contract that R offers M in this paper as a "bet" over the potential realizations of demand, in that the contract assigns positive (negative) transfers for high (low) realizations of demand. The difference between this paper and the above literature is that while they assume that the players' priors are exogenous, in this paper R uses the contract to manipulate M's prior. That is, R's problem is to design a contract that includes a "bet" that will motivate M to costly update M's prior and to accept the "bet" only in state H, as this state places high probabilities on high realizations of demand.

The rest of the paper is organized as follows. The next section describes the model and the vertical integration benchmark. Section 3 shows that it is possible to implement the vertical integration outcome if M does not need to make a costly test of the new product to learn the state, or if R observes whether M has tested the product. Section 4 considers the mechanism for motivating M to test the product when R cannot observe whether M has actually done so, and the conditions under which R will use such a mechanism. Section 5 evaluates the effect of slotting allowances on social welfare. Section 6 offers some concluding remarks. All the proofs are in the Appendix.

2. The model

Consider a market with a monopolistic retailer, R, and an upstream manufacturer, M. I focus on the case where there is no downstream competition in order to rule out, by assumption, the anti-competitive effect that slotting allowances may have in relaxing downstream competition. I also rule out the possibility of risk sharing between R and M as an explanation for slotting allowance by assuming that the two firms are risk neutral.

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eliminate the need for slotting allowances. I prefer to consider the case where M has no production costs in order to focus on M's strategic motivation to gather information (i.e., as a result of a mechanism design problem between R and M) and not on technological motivation such as the presence of production costs. In the conclusion I discuss in more details the robustness of the results to this assumption. The inverse demand for the new product is $p(q;\theta) = \theta - q$, where p and q are the price and quantity respectively, and θ represents consumers' willingness to pay for the new product. Let

$$q^*(\theta) = \arg\max_q p(q;\theta)q = \frac{\theta}{2}, \tag{1}$$

denote the quantity that maximizes the monopoly (or vertical integration) profit from selling the new product, given θ, and let

$$\pi^*(\theta) = p(q^*(\theta);\theta)q^*(\theta) = \frac{\theta^2}{4}, \tag{2}$$

denote the vertical integration profit, given θ. Since this is a new product, the parameter θ is initially unknown to both M and R. M and R believe that θ is distributed along the interval $[\theta_0, \theta_1]$ according to one of two probability functions. With probability γ, $0 < \gamma < 1$, the state is "H" and θ is drawn from a "high" distribution function, $f_H(\theta)$. With probability $1 - \gamma$, the state is "L" and θ is drawn from a "low" distribution function, $f_L(\theta)$. Suppose that $f_k(\theta) > 0$, $\forall\theta\in[\theta_0, \theta_1]$, $\forall k = \{H,L\}$. This assumption implies that any $\theta\in[\theta_0, \theta_1]$ can be drawn from both $f_H(\theta)$ and $f_L(\theta)$, and R cannot learn the state by observing θ. The cumulative distribution function for $f_k(\theta)$, k = H,L, is $F_k(\theta)$, where $F_k(\theta_0) = 0$ and $F_k(\theta_1) = 1$. Let

$$E_k\pi^*(\theta) = \int_{\theta_0}^{\theta_1} \pi^*(\theta) f_k(\theta) d\theta, \quad k = \{H, L\}, \tag{3}$$

denote the expected vertical integration profit that can obtained from the new product in state k = {H,L}, given that a vertically integrated firm can observe the realization of θ before setting $q^*(\theta)$. The condition for the difference between the two distributions is therefore that $E_H\pi^*(\theta) > E_L\pi^*(\theta)$. That is, from the viewpoint of maximizing the vertical integration profit, the new product is more profitable (in expectation) when the state is H.

It is possible to think of numerous distribution functions that satisfy this property. One obvious example is the case where $F_H(\theta)$ dominates $F_L(\theta)$ by first degree stochastic dominance (FSD), in that $F_H(\theta) < F_L(\theta)$, $\forall\theta \neq \theta_0, \theta_1$. Indeed, for any $\pi^*(\theta)$ which is increasing with θ, FSD implies that $E_H\pi^*(\theta) > E_L\pi^*(\theta)$. However, the mechanism that I am

considering is sustainable for distribution functions that are not FSD, as shown in the examples provided below.

The second product is an old product offered to R by some outside source. The demand for the old product is $p(v; q) = v - q$, where

actual demand through consumers' actual purchasing behavior. Following Chu (1992), I assume that this learning process is instantaneous, such that R learns θ immediately after placing the new product on the shelf. For example, many supermarkets use a barcode system that provides accurate, up-to-date data on actual sales. This data may facilitate the process of learning the demand from the consumers' purchasing behavior. However, R cannot learn the true demand for the new product without forgoing the potential profit on the old product.[3] Also, suppose that only R can ex-post observe θ.[4] Notice that since by assumption $f_k(\theta) > 0$, $\forall k$ = H,L, $\forall\theta\in[\theta_0, \theta_1]$, even though R observes θ ex-post, R cannot infer from θ if the test has been made, because each θ can be drawn from both distribution functions. Otherwise, R could have used this ex-post information in order to write a contract that motivates M to test the new product without having to abstract from the vertical integration outcome.

There are many potential contracts that R may offer M. I consider a general form of a menu, $(q(\theta), T(\theta))$. Accordingly, if M accepts the contract, R commits to place the new product on the shelf. Upon observing the realization of the demand, θ, R commits to choose some $q(\theta)$ from the menu and in return pay an amount $T(\theta)$, where $T(\theta)$ may be positive or negative. In Section 4, I discuss how this mechanism can be implemented by a simple non-linear tariff and an upfront slotting allowance.

The main feature of the above game is that R has two alternatives for testing the new product. The first is placing it on the shelf and observing the actual demand. The cost of this option from R's viewpoint is the forgone profit from selling the old product, π^*. The second alternative is to motivate M to test the product. However, since M does not suffer the loss of the forgone profit from replacing the old product with the new one, and since the new product is profitable for all θ in that $\pi^*(\theta) > 0$, M does not have an incentive to perform the test on behalf of R.

Notice that if $C \to 0$, the model converges to a screening model in which M has private information concerning demand without the need to test the new product (as testing the product is costless).

Next, consider a vertical integration benchmark. A vertically integrated firm M-R, which can both perform the test and choose which product to sell, has three options. First, it can perform the test, and then to sell the new (old) product if the state is H (L). The vertical integration profit from this option is: $-C + \gamma E_H\pi^*(\theta) + (1-\gamma)\pi^*$. Second, it can choose not

[3] Based on several case studies, the FTC (2003) reports that retailers usually stock new products in the store for a "reasonable" period of at least four to six months, to give the new product a fair chance to get established.

[4] An equivalent assumption is that both R and M can ex-post observe θ, but θ is not verifiable and therefore not contractible.

to perform the test but nonetheless sell the new product, and earn $\gamma E_H\pi^*(\theta) + (1 - \gamma)E_L\pi^*(\theta)$. The third option is not to perform the test, to sell the old product and earn π^*. Comparing these three options yields that there is a cutoff,

$$C^* = \begin{cases} \gamma(E_H\pi^*(\theta) - \pi^*), & \text{if } \pi^* > \gamma E_H\pi^*(\theta) + (1-\gamma)E_L\pi^*(\theta), \\ (1-\gamma)(\pi^* - E_L\pi^*(\theta)), & \text{if } \pi^* \le \gamma E_H\pi^*(\theta) + (1-\gamma)E_L\pi^*(\theta), \end{cases} \tag{4}$$

such that the vertically integrated firm performs the test if and only if $C < C^*$. This cutoff is illustrated in Figure 2. Intuitively, if π^* is sufficiently low while C is sufficiently high then the vertically integrated firm prefers to sell the new product without performing market research. Likewise, if both C and π^* are sufficiently high then the vertically integrated firm prefers to sell the old product without performing market research. Thus market research is profitable for low values of C and intermediate values of π^*.

Next, I turn to evaluating whether it is welfare enhancing to test the product under the vertical integration outcome. This welfare analysis will serve as a useful benchmark because, as I will show below, under asymmetric information R cannot write a mechanism that induces M to test the new product if antitrust authorities prohibit slotting allowances. Thus, the decision on whether to allow R to use slotting allowances under asymmetric information will be affected by the question of whether testing the new product before placing it on the shelf is welfare enhancing or not. To this end, suppose that consumers' utilities are quasi-linear such that ex-post social welfare given $q(\theta)$, gross of the cost of the test, C, is:

$$W(q(\theta);\theta) = \int_0^{q(\theta)} (\theta - q)dq = \tfrac{1}{2}q(\theta)(2\theta - q(\theta)). \tag{5}$$

Given that R sells the vertical integration quantity, ex-post social welfare from selling the new and old products are $W^*(\theta) \equiv W(q^*(\theta);\theta)$ and $W^* \equiv W(q^*(v);v)$, respectively. Notice that $W^*(\theta) = \frac{3}{8}\theta^2 = \frac{3}{2}\pi^*(\theta)$. Since $E_H\pi^*(\theta) > \pi^* > E_L\pi^*(\theta)$, it follows that $E_HW^*(\theta) > W^* > E_LW^*(\theta)$. That is, evaluated at the vertical integration quantity, R's preference to sell the new (old) product if the state is H (L) is welfare enhancing. Given that M performs the test, expected social welfare is: $-C + \gamma E_HW^*(\theta) + (1 - \gamma)W^*$. If M does not perform the test, then R sells the new product without testing it if $\pi^* < \gamma E_H\pi^*(\theta) + (1 - \gamma)E_L\pi^*(\theta)$ and social welfare is $\gamma E_HW^*(\theta) + (1 - \gamma)E_LW^*(\theta)$. Otherwise, R sells the old product and social welfare is W^*. Comparing terms, it is welfare enhancing to test the new product if $C < C_W^*$, where:

$$C_W{}^* = \begin{cases} \gamma(E_H W^*(\theta) - W^*), & \text{if } \pi^* > \gamma E_H \pi^*(\theta) + (1-\gamma) E_L \pi^*(\theta), \\ (1-\gamma)(W^* - E_L W^*(\theta)), & \text{if } \pi^* \le \gamma E_H \pi^*(\theta) + (1-\gamma) E_L \pi^*(\theta), \end{cases} \tag{6}$$

Equation (6) is similar to (5), except that the cutoff of C is determined according to social welfare instead of total industry profits. Figure 2 illustrates C_W* as a function of π*. Substituting $W^*(\theta) = \frac{3}{2}\pi^*(\theta)$ into (6), it follows that $C_W^* = \frac{3}{2} C^*$, implying that the vertically integrated firm tests the new product less than is socially desirable. Intuitively, a vertically integrated firm does not internalize the effect of placing the product with the most value to the consumers on the shelf.

3. Full information benchmark

The aim of this section is to show that slotting allowances do not emerge, in the context of this model, under full information, thus emphasizing the type of asymmetric information that induces R to charge slotting allowances.

To this end, it is possible to think of three full information benchmarks. First, consider a benchmark case in which R can perfectly observe whether M has performed the test, and the outcome of the test. This can be the case if, for example, M has a reputation for honestly conducting market research and revealing all the necessary data, a reputation that R believes that M wants to preserve. If R chooses to motivate M to perform the test, then R can offer a contract according to which R commits that if M provides evidence that it has performed the test and the result indicates that the state is H, then R will reserve space shelf for the new product and offer a menu $(q(\theta),T(\theta)) = (q^*(\theta),C/\gamma)$. M's expected profit from accepting this offer and performing the test is: $-C + \gamma(C/\gamma) + (1-\gamma)0 = 0$. Thus M will agree to conduct the test, and R earns the vertical integration profit. If R chooses not to motivate M to perform the test but nonetheless chooses to sell the new product, R can offer a contract $(q(\theta),T(\theta)) = (q^*(\theta), 0)$, which M will accept without conducting the test, and R earns the vertical integration profit. Since R earns the vertical integration profit in both cases, R will follow the same decision rule as in (4) concerning whether to motivate M to perform the test, and thus fully implement the vertical integration outcome and earn the vertical integration profit. By revealed preference, R cannot do better than offering the above contract.

A second benchmark is the case where M is privately informed about the state without having to perform the test. This second benchmark corresponds to the case where $C = 0$. Indeed, substituting $C = 0$ in the contract described above indicates that R can ask M to reveal its private information and offer the contract $(q(\theta),T(\theta)) = (q^*(\theta), 0)$ in case M indicates that the state is H. M does not earn positive profit by accepting the contract if the state is L, and

therefore has no incentive to misrepresent its private information. Therefore, again R can implement the vertical integration profit. Notice that this last result differs from Chu (1992), Lariviere and Padmanabhan (1997) and Desai (2000) that show that when the manufacturer has private information concerning the demand, the manufacturer signals the demand by means of slotting allowances. The difference in results emerges because in this model, R has the bargaining power to make the take-it-or-leave-it offer to M. With no bargaining power, M has no incentive to signal its private information.

A third full information benchmark is the case where M needs to perform the costly test to learn the state and R can observe whether M has performed the test or not. But unlike the first benchmark, M is privately informed regarding the result of the test. In this case a contract that commits to a menu ($q^*(\theta),C/\gamma$), contingent on observing that M performed the test and on M's report that the state is H, is insufficient because M will prefer to report that the result is H (in order to convince R to deal with M and pay $T(\theta) = C/\gamma$) even if the true state turns out to be L. However, R can offer the alternative mechanism, in which R pays $T = C$ in return for conducting the test (regardless of its outcome) and offers a contract $(q(\theta),T(\theta)) = (q^*(\theta),0)$ if M reports that the result is that the state is H. Here M has no incentive to misreport the true state because its profit depends only on whether it has performed the test or not.

To conclude, this section reveals three main results. First, under the three benchmark cases described above R can implement the vertical integration profit. Second, in these three benchmarks R does not need to use slotting allowances, in that $T(\theta)$ is always nonnegative. Third, in these three benchmarks $T(\theta)$ is independent of θ. As I will show below, these three results will no longer hold under asymmetric information.

4. Asymmetric information

This section describes the case of asymmetric information, in which M has to perform the costly test in order to learn the state, and performing the test, as well as the results of the test, is M's private information. The main conclusion of this section is that under such informational structure, the optimal mechanism for motivating M to test the new product includes slotting allowances. Also, as under full information, R will prefer to use this mechanism if C is sufficiently low. However, slotting allowances will force R to distort its quantity away from the full information level.

To this end, I will proceed as follows. First, I will define and solve for the optimal mechanism (from R's viewpoint) that induces M to perform the test under asymmetric information. Then, I will describe how R can implement such a mechanism with a possibly enforceable contract. Finally, I will move to the question of whether R will indeed find it

optimal to use such a mechanism under asymmetric information, or instead choose to sell the new product without testing it first, or to sell the old product.

Because R cannot observe whether M has performed the test and the results of the test, R faces the problem of moral hazard and adverse selection: R needs to motivate M to perform the test, and to reveal its outcome. Suppose that R offers a mechanism that includes a menu $(q(\theta),T(\theta))$. If M accepts the contract, then R commits to place the new product on the shelf. Then, after observing θ, R has to choose a line from the menu by reporting θ. At this point, R cannot refuse to report a θ. Notice that R's mechanism is a two-dimensional menu, that I can rewrite as: $\{0, (q(\theta),T(\theta))\}$. The "horizontal" dimension of the menu is that M needs to choose between "0" (namely, not accepting the contract) and $(q(\theta),T(\theta))$, where the mechanism should ensure that M will test its product and choose 0 if the state is L and $(q(\theta),T(\theta))$ otherwise. Notice that since R cannot observe whether M has tested the new product, there is no loss of generality in focusing on mechanisms that does not compensate M in state L (unlike the third full information benchmark described in Section 3). The "vertical" dimension of the menu is that after observing the realization of θ, R needs to choose a line from $(q(\theta),T(\theta))$, and the mechanism should ensure that R will choose the line that corresponds to the true θ. R's problem is therefore:

$$\max_{(q(\theta),T(\theta))} E_H\{p(q(\theta);\theta)q(\theta)-T(\theta)\}, \tag{7}$$

$$\begin{aligned}
\text{s.t.}\quad &(IC_M^{ex-post}) && E_L T(\theta) \le 0,\\
&(IR_M^{ex-post}) && E_H T(\theta) \ge 0,\\
&(IC_M^{ex-ante}) && -C + \gamma E_H T(\theta) \ge \gamma E_H T(\theta) + (1-\gamma) E_L T(\theta),\\
&(IR_M^{ex-ante}) && -C + \gamma E_H T(\theta) \ge 0,\\
&(IC_R) && \theta = \arg\max_{\tilde{\theta}} \left(p(q(\tilde{\theta});\theta)q(\tilde{\theta}) - T(\tilde{\theta})\right).
\end{aligned}$$

The first two constraints relate to M's ex-post behavior. The $IC_M^{ex-post}$ constraint is M's ex-post incentive compatibility constraint, which ensures that after performing the test and revealing that the state is L, M prefers not to accept the contract. The $IR_M^{ex-post}$ constraint is M's ex-post individual rationality (or participation) constraint, which ensures that after performing the test and observing that the state is H, M will accept the contract. The next two constraints relate to M's ex-ante behavior. The $IC_M^{ex-ante}$ constraint ensures that M prefers to perform the test, given that afterwards it will accept the contract only if the state is H (which occurs with probability γ), over accepting the contract without testing the new product firsthe

ensures that M prefers to perform the test over not interacting with R. The first four constraints are derived under the assumption that M expects R to choose the line from the menu that corresponds to the true θ. Therefore, a fifth constraint, IC_R, is R's incentive compatibility, which ensures that given that M has accepted the contract and R has observed the realization of θ, R will choose the corresponding line from the menu by truthfully reporting θ. This last constraint emerges because of R's inability to contract on the actual realization of θ. Notice that IC_R is constructed under the assumption that given that R reports a θ and receives a corresponding $q(\theta)$, R always sells the entire quantity. I will discuss the robustness of the mechanism to this assumption below.

I now turn to solving for the optimal mechanism. To this end, I need to rewrite the various constraints. Starting with constraints $IC_M^{ex-ante}$ and $IR_M^{ex-ante}$, they can be rewritten as:

$$E_L T(\theta) \leq -\frac{C}{1-\gamma}, \tag{8}$$

and:

$$E_H T(\theta) \geq \frac{C}{\gamma}, \tag{9}$$

respectively. The intuition behind inequalities (8) and (9) is that the expected payment by R to M should be low enough in state L such that M will not agree to the contract without testing its product first, while the expected payment in state H should be high enough to compensate for the cost of the test. These two inequalities provide two insights. First, they imply that $IC_M^{ex-post}$ and $IR_M^{ex-post}$ are not binding, as they are satisfied whenever (8) and (9) are satisfied, and I can therefore ignore them. Second, and more importantly, given that both (8) and (9) are binding (as I will show below), they reveal that the optimal mechanism requires that $T(\theta) > 0$ for some values of θ, while $T(\theta) < 0$ for others. That is, unlike the full information mechanism in which $T(\theta) = C/\gamma$ such that $T(\theta)$ is independent of θ, here $T(\theta)$ should be positive for some realizations of θ and negative for others. This result however implies that R may have an incentive to misreport θ. In particular, if for some θ, $T(\theta) > 0$, R may have an incentive to report some $\tilde{\theta} \neq \theta$ that satisfies $T(\tilde{\theta}) < 0$ in order to gain a fixed payment from M, and IC_R no longer holds. I therefore turn to rewriting IC_R. To this end, let

$$U(\theta;\tilde{\theta}) = p(q(\tilde{\theta});\theta)q(\tilde{\theta}) - T(\tilde{\theta}), \tag{10}$$

and let $U(\theta) = U(\theta;\theta)$ denote R's ex-post profit as a function of θ. We have:

Lemma 1: *Suppose that* $q(\theta)$ *is continuous, and twice differentiable. Then, necessary and sufficient conditions for* IC_R *is that* $q(\theta)$ *is increasing with* θ *and R earns:*

$$U(\theta) = U(\theta_0) + \int_{\theta_0}^{\theta} q(\hat{\theta}) d\hat{\theta}\,. \tag{11}$$

Intuitively, in order to induce R to ex-post report θ, R needs to specify R's ex-post "information rents", defined in (11). These information rents differ from the usual information rents in the principal-agent literature in that here, the principal, R, leaves them not to the agent, but to itself. From (11) the marginal information rents are $U'(\theta) = q(\theta)$. Substituting (11) into (10) and rearranging, IC_R implies that:

$$T(\theta) = p(q(\theta);\theta)q(\theta) - \int_{\theta_0}^{\theta} q(\hat{\theta}) d\hat{\theta} - U(\theta_0)\,, \tag{12}$$

Equation (12) defines the $T(\theta)$ that R can set while maintaining IC_R, given $q(\theta)$. As stated above, setting $T'(\theta) \neq 0$ for at least some values of θ may affect R's ex-post report of θ. Equation (12) defines the relation between $T(\theta)$ and the $q(\theta)$ that R needs to set ex-ante in order to prevent R from ex-post misrepresenting θ. In other words, (12) defines the "cost" of setting $T'(\theta) \neq 0$, in terms of the distortion in $q(\theta)$, in comparison with the full information $q^*(\theta)$, that R needs to set in order to set $T'(\theta) \neq 0$. To see these costs, it follows from (12) that

$$T'(\theta) = q'(\theta)(\theta - 2q(\theta)) = 2q'(\theta)(q^*(\theta) - q(\theta))\,, \tag{13}$$

where the second equality follows since $q^*(\theta) = \theta/2$. Since Lemma 1 requires that $q'(\theta) > 0$, (13) is positive (negative) if $q(\theta) < (>)\ q^*(\theta)$. Therefore, if R chooses to maintain constraints (8) and (9) by, say, setting $T'(\theta) > 0$, then R will have an ex-post incentive to understate θ in order to benefit from the decrease in $T(\theta)$, and it follows from (13) that R will have to ex-ante offset this incentive by distorting $q(\theta)$ downwards. Likewise, if R sets $T'(\theta) < 0$, then R will have an ex-post incentive to overstate θ which from (13), R will offset by distorting $q(\theta)$ upwards.

After rewriting IC_R, I turn to using Lemma 1 to rewrite R's problem. Substituting (12) into (8) and (9), the two constraints become:

$$U(\theta_0) \leq E_H\left(p(q(\theta);\theta)q(\theta) - \int_{\theta_0}^{\theta} q(\hat{\theta}) d\hat{\theta}\right) - \frac{C}{\gamma}\,, \tag{14}$$

$$U(\theta_0) \geq E_L\left(p(q(\theta);\theta)q(\theta) - \int_{\theta_0}^{\theta} q(\hat{\theta})d\hat{\theta}\right) + \frac{C}{1-\gamma}. \tag{15}$$

Since (7) is decreasing with $E_H T(\theta)$ and $E_H T(\theta)$ is decreasing in $U(\theta_0)$, (14) is always binding. Substituting (14) (in parity) into (7) and (15), I can rewrite R's problem as:

$$\max_{q(\theta)} E_H \quad p(q(\;);\;)q(\;) \quad \frac{C}{\;}$$

mechanism. The first proposition describes the main features of the solution, given any pair of cumulative distribution functions $F_H(\theta)$ and $F_L(\theta)$.

Proposition 1: *There is an interior solution to R's problem if C is sufficiently small and* γ *is intermediate. In this solution,* $T^{**}(\theta)$ *is increasing (decreasing) with* θ and $q^{**}(\theta) < (>) q^*(\theta)$ *if* $F_L(\theta) > (<) F_H(\theta)$. *The gap* $|q^*(\theta) - q^{**}(\theta)|$ *is increasing with the gap* $|F_L(\theta) - F_H(\theta)|$ *and with C, and decreasing (increasing) with* γ *for* $\gamma < (>) 1/2$.

As it would be more convenient to illustrate the intuition for the results for a given relation between the two distribution functions, I start by considering the case where $F_H(\theta)$ dominates $F_L(\theta)$ by FSD, as illustrated in Figure 3. The following corollary follows directly from Proposition 1:

Corollary 1: *Suppose that* $F_H(\theta) < F_L(\theta)$, $\forall\theta\in(\theta_0, \theta_1)$. *Then, in the interior solution to R's problem,* $T^{**}(\theta)$ *is increasing with* θ, *and* $T(\theta_0) < -C/(1-\gamma)$ *while* $T(\theta_1) > C/\gamma$. *Moreover,* $q^{**}(\theta) < q^*(\theta)$, $\forall\theta \neq \theta_0, \theta_1$ *and* $q^{**}(\theta) = q^*(\theta)$ *otherwise.*

The results of Corollary 1, given that the problem indeed has an interior solution, are illustrated in panel (a) of Figure 3. The figure shows that in comparison with the vertical integration contract, $T(\theta)$ is distorted upwards (downwards) for high (low) realizations of θ, while $q(\theta)$ is distorted downwards except for the two extremes θ_0 and θ_1. From Proposition 1, this downwards distortion becomes more significant as $F_L(\theta) - F_H(\theta)$ or C become higher, while γ affects it in a nonlinear way. The intuition for this result is the following. Since it is more likely to expect high (low) realizations of θ in state H (L), R ensures that M will find it profitable to test the new product before accepting the contract by setting a $T^{**}(\theta)$ which is increasing in θ. This way, M's ex-post profit is positively related to the realization of θ, and therefore M earns positive expected profit only if the distribution function indeed places high probabilities on high realizations of θ. More precisely, setting $T'(\theta') > 0$ for a certain θ' implies that R decreases $T(\theta)$ for all $\theta\in[\theta_0, \theta']$, and increases $T(\theta)$ for all $\theta\in[\theta', \theta_1]$. If it is more likely that θ is lower than θ' in state L than in state H, in that $F_L(\theta) > F_H(\theta)$, then doing so increases the gap $E_HT(\theta) - E_LT(\theta)$, thus making (17) less tight. Therefore, it is profitable for R to set $T'(\theta') > 0$ if $F_L(\theta') > F_H(\theta')$. However, this mechanism only works if M indeed expects R to ex-post choose the "right" contract from the menu. From the discussion above, if $T'(\theta) > 0$, R has an ex-post incentive to understate θ, implying that R has to ex-ante distort $q(\theta)$ downwards. The optimal solution balances between the benefit of setting $T'(\theta) > 0$, and

the cost of having to distort $q(\theta)$ as a result. The larger the gap $F_L(\theta) - F_H(\theta)$, the more effective it becomes to set $T'(\theta) > 0$ to sustain (17); thus R sets a higher $T'(\theta)$, which in turn require a higher distortion in $q(\theta)$. The higher the cost of performing the test, C, tighter the constraint (17) becomes and the higher the $T'(\theta)$ needed to sustain (17), again at the cost of increasing the downwards distortion in $q(\theta)$. Finally, γ has two conflicting effects on the optimal menu. On one hand, a high γ increases M's profit from testing the new product before accepting the contract because it becomes more likely that M will observe that the state is H and therefore accept the contract ex-post. Thus, M's participation constraint, $IR_M^{ex-ante}$, becomes less restrictive. At the same time, a high γ increases M's profit from accepting the contract without testing the new product first, because the state will most likely turn out to be H anyway. Thus, the $IC_M^{ex-ante}$ constraint becomes more restrictive. As (8) and (9) indicate, these two effects are the strongest for extreme values of γ: as γ becomes closer to one (zero), it becomes impossible to satisfy (8) ((9)). Therefore, the distortion in $q(\theta)$ is decreasing (increasing) with γ for $\gamma > (<)\ 1/2$.

Notice that an interior solution to R's problem can only be ensured if C is not too high or γ is intermediate. Intuitively, if C is high enough or γ is either close to zero or one, then the resulting distortion in $q(\theta)$ can potentially be too significant, such that there will be some realizations of θ in which $q'^{**}(\theta) < 0$, in violation of the conditions of Lemma 1. Also, the proof of Proposition 1 shows that the second order condition for R's problem can be ensured only if C is low or γ is close to 1/2. Otherwise, R's problem as defined above does not have an interior solution. The critical values of C and γ that can give rise to such a problem, if at all, depend on the specification of the two distribution functions. To avoid making additional assumptions on the distribution functions, I will focus the discussion on the case where C is low or γ is intermediate, for which Proposition 1 ensures that there is an interior solution.

Next consider distribution functions in which for some realizations of θ (though not all), $F_L(\theta) < F_H(\theta)$. As explained above, R finds it optimal to set $T'(\theta) > 0$ if $F_L(\theta) > F_H(\theta)$. The same intuition can be reversed for realizations of θ that satisfy $F_L(\theta) < F_H(\theta)$, in which case R needs to set $T'(\theta) < 0$ to make (17) less tight. Panels (b) and (c) of Figure 3 illustrate two such cases. Panel (b) illustrates a case where there is a cutoff, θ^A, such that $F_L(\theta) > (<)\ F_H(\theta)$ for $\theta \in [\theta_0, \theta^A]$ ($\theta \in [\theta^A, \theta_1]$). Notice that θ^A has to be sufficiently high to ensure that H is indeed the superior state. Applying Proposition 1, in this case R distorts the optimal quantity downwards (upwards) for low (high) realizations of θ, but with no distortion for θ_0, θ^A and θ_1. Also, $T(\theta)$ is increasing with θ for $\theta \in [\theta_0, \theta^A]$ and decreasing otherwise. Notice that since $E_H T(\theta) = C/\gamma$, while $E_L T(\theta) = -C/(1-\gamma)$, it has to be that $T(\theta^A) > C/\gamma$, though the values of

$T(\theta_0)$ and $T(\theta_1)$ eventually depend on the specific functional form of the distribution functions. Panel (c) illustrates the opposite case, in which $F_L(\theta) < (>) F_H(\theta)$ for $\theta \in [\theta_0, \theta^B]$ ($\theta \in [\theta^B, \theta_1]$). Here θ^B has to be sufficiently low to ensure that H is the superior state. Applying Proposition 1, in this case the optimal quantity is distorted upwards (downwards) for low (high) realizations of θ, but again there is no distortion for θ_0, θ^B and θ_1. Here, $T(\theta)$ is decreasing with θ for $\theta \in [\theta_0, \theta^B]$ and increasing otherwise. Consequently, it has to be that $T(\theta^B) < -C/(1-\gamma)$, but again the values of $T(\theta_0)$ and $T(\theta_1)$ depend on the specific functional form of the distribution functions. Notice that in the two cases described above, the upwards distortion in the quantity may occur, if at all, for only a subset of the interval $[\theta_0, \theta_1]$, because the assumption that $E_H\pi^*(\theta) > E_L\pi^*(\theta)$ requires that $F_H(\theta) < F_L(\theta)$ for at least some realizations of θ.

Next I turn to the issue of implementation. The optimal mechanism suffers from two implementation problems. First, it requires R to pay M if θ turns out to be high, while M actually pays R otherwise. In the latter case, M may clearly refuse both to produce a certain quantity for R, and pay for doing so, instead of being compensated. Second, IC_R is derived under the assumption that R sells all the quantity it buys from M. Clearly, R can potentially buy a certain quantity and then offer consumers a lower quantity, while disposing of the rest. The proposition below offers an alternative, more feasible contract for implementing the mechanism:

Proposition 2: *Suppose that* $F_H(\theta) < F_L(\theta)$, $\forall\theta \in (\theta_0, \theta_1)$. *Then, R can implement the contract* ($q^{**}(\theta), T^{**}(\theta)$) *by offering a contract* (S, $\tilde{T}(q)$), *where* $S > 0$ *is an upfront slotting allowance from M to R and* $\tilde{T}(q) > 0$ *is a payment from R to M contingent on q. To this end, R sets* $S = -T^{**}(\theta_0)$ *and*

$$\tilde{T}(q) = \begin{cases} 0, & \text{if } q \le q^{**}(\theta_0), \\ -T^{**}(\theta_0) + T^{**}(\tilde{\theta}(q)), & \text{if } q > q^{**}(\theta_0), \end{cases} \tag{18}$$

where $\tilde{\theta}(q)$ *is the inverse function of* $q^{**}(\theta)$ and $\tilde{T}(q)$ *is increasing with q.*

Proposition 2 explains why retailers sometimes charge upfront slotting allowances. Intuitively, upfront slotting allowances enable R to solve the enforcement problem associated with having $T(\theta) < 0$ for some realizations of θ, by asking M to pay upfront the highest negative transfer under the original mechanism, and then paying back to M, after observing the realization of θ. Notice however that by doing so, M covers (ex-post) the cost of the slotting allowances only if the demand is sufficiently high. This result may explain why, in

the presence of slotting allowances, financially constrained manufacturers suffer from a competitive disadvantage over manufacturers with more substantial financial resources. A manufacturer with "deep pockets" may be able to afford to pay high slotting allowances, even though its potential ex-post profit may not cover the initial investment. A financially constrained manufacturer, however, may not be able to finance such slotting allowances by means of loans, because if the realization of demand is low, the manufacturer will default. This in turn may motivate a retailer to prefer to deal with financially unconstrained manufactures.[5]

If $F_H(\theta) < F_L(\theta)$, $\forall\theta\in(\theta_0, \theta_1)$, then the alternative mechanism also solves the second problem mentioned above. In this case, $\tilde{T}(q)$ is always increasing with q, implying that R will only buy the quantity that it intends to sell to consumers. This however is not the case if for some realizations of θ, $F_H(\theta) > F_L(\theta)$. In such cases, $T(\theta)$, and therefore the equivalent $\tilde{T}(q)$ are decreasing with θ (and therefore with q). This means that R will have an incentive to buy a high quantity in order to benefit from paying a lower $\tilde{T}(q)$, while afterwards selling only a lower quantity than q, in violation of IC_R. R can solve this problem by committing not only to place the new product on the shelf, but also to have a certain quantity in place until it is sold out. Such a commitment is clearly difficult to enforce, though not entirely impossible.

The last step in solving for the optimal mechanism is to derive the conditions under which R indeed prefers to use the mechanism under asymmetric information. R's expected profit from using the mechanism is: $-C + \gamma E_H\pi^{**}(\theta) + (1-\gamma)\pi^*$, where $\pi^{**}(\theta) = p(q^{**}(\theta);\theta)q^{**}(\theta)$. As under the full information benchmark, R's alternatives are to sell the new product without motivating M to test it first, in which case R earns $\gamma E_H\pi^*(\theta) + (1-\gamma)E_L\pi^*(\theta)$. The second alternative is to offer the old product and earn π^*. Comparing the three options yields:

Proposition 3: *Under asymmetric information there is a cutoff, C^{**}, such that R uses the mechanism if and only if $C < C^{**}$, where $0 < C^{**} < C^*$.*

Notice that Proposition 3 does not depend on whether $F_H(\theta)$ is higher or lower than $F_L(\theta)$. Intuitively, using the mechanism under asymmetric information forces R to distort its quantity away from the vertical integration quantity, either upwards or downwards, depending on the gap $F_H(\theta) - F_L(\theta)$. In both cases, total industry profit is lower than under full information, making it less desirable for R to motivate M to perform the test.

[5] For example, the Federal Trade Commission (2001) found that small manufacturers described slotting allowances as "a major stumbling block for us to enter into any large distribution network" (p. 19). Also, they found that small manufacturers seeking to supply retail grocery markets have difficulties in finding sources of equity capital because of their size.

5. Social welfare

In this section I discuss the effect of slotting allowances on social welfare. As stated in the Introduction, slotting allowances may raise the concern of antitrust authorities because they may have anti-competitive effects but at the same time enhance efficiency in allocating scarce shelf space. Proposition 2 above provides some theoretical support for the claim that slotting allowances may have the anti-competitive effect of discriminating against small manufacturers, as it shows that manufacturers may not cover the expenditure on slotting allowances if the demand is low, making it more difficult for financially constraint manufacturers to finance the initial expenditure on slotting allowances.

assumptions concerning the distribution functions, because unlike the full information benchmark in which $W^*(\theta)$ is independent of the distribution functions, C, and γ, under asymmetric information, in which $q^{**}(\theta)$ is distorted away from its full information level as described in Proposition 1, $q^{**}(\theta)$, and therefore $W^{**}(\theta)$, ultimately depend on the gap $F_H(\theta) - F_L(\theta)$, C and γ. Nevertheless, such a comparison intuitively involves a tradeoff between two conflicting effects. The first effect is the welfare-enhancing property of enabling R to better allocate its scarce shelf space for the product which is most likely to be valuable to consumers. Because of this effect, under full information R always motivates M to test its product when it is welfare enhancing to do so, in that $C^* < C_W^*$. The second effect is that in contrast with the full information case, testing the new product under asymmetric information involves a mechanism that distorts the quantity downwards for at least some realizations of θ, and for all realizations of θ if $F_H(\theta)$ dominates $F_L(\theta)$ by FSD. As described in Proposition 1, this distortion increases with C or as γ becomes close to either one or zero. In such cases the second adverse effect may offset the first effect, and a social planner will choose to prevent R from using slotting allowances.

In what follows I illustrate this tradeoff by considering a simple numerical example that shows that it is possible to find parameters under which the first or second effects dominate, such that slotting allowances may either increase or decrease social welfare. Suppose that θ is distributed along the interval [0, 1], according to one of two distribution functions:

$$f_H(\theta) = \begin{cases} \frac{4}{5}, & if \;\; \theta \in [0, \frac{1}{2}], \\ \frac{6}{5}, & if \;\; \theta \in [\frac{1}{2}, 1], \end{cases} \qquad f_L(\theta) = \begin{cases} \frac{6}{5}, & if \;\; \theta \in [0, \frac{1}{2}], \\ \frac{4}{5}, & if \;\; \theta \in [\frac{1}{2}, 1]. \end{cases} \tag{19}$$

The difference between the two distribution functions is that $f_H(\theta)$ places a higher probability on values of θ above 1/2 than does $f_L(\theta)$. The cumulative distribution functions are

$$F_H(\theta) = \begin{cases} \frac{4}{5}\theta, & if \;\; \theta \in [0, \frac{1}{2}], \\ \frac{1}{5}(6\theta - \frac{1}{2}), & if \;\; \theta \in [\frac{1}{2}, 1], \end{cases} \qquad F_L(\theta) = \begin{cases} \frac{6}{5}\theta, & if \;\; \theta \in [0, \frac{1}{2}], \\ \frac{1}{5}(4\theta + 1), & if \;\; \theta \in [\frac{1}{2}, 1]. \end{cases} \tag{20}$$

Notice that in this example, $F_H(\theta)$ dominates $F_L(\theta)$ by FSD. Suppose also that $\gamma = \frac{1}{2}$. The expected vertical integration profits for the two distribution functions are $E_H\pi^*(\theta) \cong 0.0958$ and $E_L\pi^*(\theta) \cong 0.0708$.

As it turns out that it is impossible to solve the model analytically even in this simple example, I solve it numerically as follows. First, I solve for $q^{**}(\theta)$ and $T^{**}(\theta)$ for an interval

of discrete values of C that varies between 0 and 0.0035 with intervals of 0.0001. Figure 4 shows the equilibrium $q^{**}(\theta)$ and $T^{**}(\theta)$ for three representative values of C: 0.001, 0.002 and 0.003. Notice that indeed we have that $T^{**}(\theta)$ is increasing with θ, and $q^{**}(\theta)$ is distorted downwards in comparison with the full information contract. These features become more significant the higher is C. For $C > 0.00358$, $q^{**}(\theta)$ becomes negative for low values of θ, and R has to choose a "shut down" policy in which it does not deal with M for low realizations of θ. I can ignore such a corner solution because, as I will show below, for such high values of C R will not want to use the mechanism to begin with. Notice also that the equilibrium $q^{**}(\theta)$ is not continuous, which violates the condition for IC_R in Lemma 1. In the Appendix I show that for this numerical example, the contract still satisfies IC_R.

The next step in solving the problem numerically is to use the different solutions of $q^{**}(\theta)$ and $T^{**}(\theta)$ (for the different values of C) to calculate $E_H\pi^{**}(\theta)$, $E_L\pi^{**}(\theta)$, $E_HW^{**}(\theta)$ and $E_LW^{**}(\theta)$. Then, I can numerically solve for the values of π^* that makes R and the social planner indifferent between using the mechanism or not, given the numerical values of C. Recall that Proposition 3 indicates that such a cutoff exists for any distribution functions. As for the social planner, such a cutoff exists because $q^{**}(\theta)$ is decreasing with C, implying that the social welfare from using the test, $-C + \gamma E_HW^{**}(\theta) + (1-\gamma)W^*$, is decreasing with C, where for $C \to 0$, it is always welfare enhancing to test the new product.

Figure 5 shows the pairs of C and π^* that makes R (the thin line) and the social planner (the bold line) indifferent between using the mechanism or not. The figure reveals that for a given π^*, the first, welfare-enhancing effect of slotting allowances, namely, enabling R to efficiently allocate its scarce shelf space, dominates if C is low. For high values of C, the downwards distortion in the quantity under slotting allowances becomes stronger, and the second effect dominates in that slotting allowances becomes welfare reducing. Likewise, for a given C, slotting allowances are welfare reducing if π^* is either too low or too high.

To conclude, while in the vertical integration (or full information case) R motivates M to test the new product less than is socially optimal (in that $C^* < C_W^*$), under the numerical example of symmetric information R motivates M to test the new product more than is socially optimal. In the full information case, R does not internalize the positive effect that testing the new product has on consumers. In contrast, under asymmetric information R does not internalize the negative effect that distorting the quantity downwards has on consumers. Notice that the above example focuses on the case where $F_H(\theta)$ dominates $F_L(\theta)$ by FSD. If there are some values of θ in which $F_H(\theta) > F_L(\theta)$, then slotting allowances may have a third positive effect on welfare, because for these realizations of θ R distorts its quantity above the vertical integration quantity. This means that the cutoff point in C from which slotting

allowances become welfare reducing will increase, making slotting allowances more socially desirable.

For antitrust policy, this numerical example shows that even after ruling out the potential anti-competitive effects slotting allowances, they may still have conflicting effects on welfare. Therefore, antitrust authorities should not necessarily tolerate anti-competitive effects of slotting allowances on the grounds that they have efficiency gains, because the presence of such efficiency gains depends on market conditions.

6. Conclusion

This paper considers the problem of motivating a manufacturer to gather information concerning the demand for its new product. The main result of the paper is that the optimal mechanism includes slotting allowances because of the combinations of two factors. First, the retailer has the bargaining power to make a take-it-or-leave-it offer to the manufacturer. Second, the manufacturer needs to invest in the costly process of gathering information concerning demand and the gathering of information is not observable to the retailer. By demanding slotting allowances, the retailer makes the profit of the manufacturer contingent on the ex-post realization of demand, in a manner that makes it unprofitable for the manufacture to accept the contract without testing its new product first and verifying that the demand is expected to be high. Slotting allowances therefore have the welfare-enhancing property of enabling the retailer to efficiently use its scarce shelf space for the product which is expected to yield the highest benefit for consumers. However, slotting allowances also have the disadvantage that they force the retailer to distort the quantity it offers consumers. Intuitively, since slotting allowances serves as a means of "punishing" the manufacturer for low realizations of demand, the retailer has to distort its quantity in order to avoid the temptation to ex-post "punish" the manufacturer even when the demand turns out to be high. Using a numerical example, I show that because of these two effects, slotting allowances may increase or decrease social welfare, in comparison with a regime in which antitrust authorities prohibit slotting allowances.

For antitrust policy, this result indicates that slotting allowances may decrease social welfare even without potential anti-competitive effects. The model however suggests that such anti-competitive effect may still exist. In particular, when the demand is low, a manufacturer will not be able to cover these upfront payments with the ex-post revenues from selling to the retailer. This in turn may prevent financially constraint manufacturers from acquiring access to shelf space, and reduce welfare because they motivate retailers to allocate shelf space according to manufacturers' ability to pay slotting allowances instead of the manufacturers' quality.

The paper makes three simplifying assumptions that are worth noting. First, as I described in Section 2, I assume that M has no production costs. If instead M has production costs, $TC(q(\theta))$, then the left hand side on constraint (8) now becomes $T(\theta) - TC(q(\theta))$. This implies that if $TC(q(\theta_0))$ is sufficiently high (say, because of fixed costs), then the equilibrium contract may specify $T(\theta_0) > 0$ while still maintaining (8). That is, R may still leave M with negative profits for θ_0 even without charging slotting allowances, simply by not agreeing to compensate M for the full amount of M's production costs. Consequently the size of slotting allowances in this model only measures the net strategic motivation for slotting allowances, which are discounted by the presence of production costs. For antitrust policy, this argument makes the results of this model stronger because it implies that even negligible observable slotting allowances can indicate the presence of higher "hidden" slotting allowances because with the presence of production costs manufacturers' losses in low realizations of demand can be higher than just their expenditure on slotting allowances.

Second, I assume that gathering information reveals to M that the demand is drawn from one of only two potential distribution functions, and that R wants to sell the new product for only one of these two distribution functions. In this case, R does not need to leave M with ex-ante information rents. It is possible to think of a more general setting in which there are $n > 3$ potential distribution functions, and that R wants to sell the new product for m distribution functions, where $n > m > 1$. Under such a setting R may have to leave M with ex-ante information rents. In other words, M's ex-post incentive compatibility constraints, which are not binding in my model, may now bind. This in turn may create another motivation for R to distort its quantity, now with the purpose of reducing M's information rents. For future research, I think that it would be interesting to investigate the direction of the quantity distortion in such a case. A third simplifying assumption is that M and R are risk neutral. Risk aversion may, by itself, create a motivation for R to use slotting allowances in order to share the risk between the two firms. Also, risk aversion may affect R's preferences concerning which of the two states is the preferable one. This in turn may affect the direction of the quantity distortion. For future research, I think that it would be interesting to introduce risk aversion to this mechanism design problem.

Appendix

Following are the proofs of Lemmas 1 and 2 and Propositions 1 – 3.

Proof of Lemma 1:

Differentiating (10) and using the envelop theorem,

$$U'(\theta) = \frac{\partial}{\partial \theta} U(\theta;\tilde{\theta})\Big|_{\tilde{\theta}=\theta} = q(\theta)\ . \qquad \text{(A-1)}$$

Integrating (A-1) yields (11). To see that $q'(\theta) > 0$ satisfies IC_R, using (12), R's ex-post profit is:

$$\begin{aligned} U(\theta;\tilde{\theta}) &= p(q(\tilde{\theta});\theta)q(\tilde{\theta}) - \left(p(q(\tilde{\theta});\tilde{\theta})q(\tilde{\theta}) - \int_{\theta_0}^{\tilde{\theta}} q(\theta)d\theta - U(\theta_0) \right) \\ &= (\theta - q(\tilde{\theta}))q(\tilde{\theta}) - \left((\tilde{\theta} - q(\tilde{\theta}))q(\tilde{\theta}) - \int_{\theta_0}^{\tilde{\theta}} q(\theta)d\theta - U(\theta_0) \right). \end{aligned} \qquad \text{(A-2)}$$

Differentiating (A-2) with respect to $\tilde{\theta}$ yields:

$$\frac{\partial}{\partial \tilde{\theta}} U(\theta;\tilde{\theta}) = (\theta - \tilde{\theta})q(\tilde{\theta}) = 0\ . \qquad \text{(A-3)}$$

Thus R sets $\tilde{\theta} = \theta$. The second order condition implies that:

$$\frac{\partial^2}{\partial^2 \tilde{\theta}} U(\theta;\tilde{\theta})\Big|_{\tilde{\theta}=\theta} = -q'(\theta) < 0\ , \qquad \text{(A-4)}$$

which requires that $q'(\theta) > 0$.

Proof of Lemma 2:

Substituting $q(\theta) = q^*(\theta)$ in (12) yields $T(\theta) = \theta_0^2/4 - U(\theta_0)$, $\forall\theta\in[\theta_0, \theta_1]$. However, substituting $T(\theta) = \theta_0^2/4 - U(\theta_0)$ into (17) yields that the left hand side of (17) equals to zero, while the right hand side is positive because $C > 0$ and $0 < \gamma < 1$, in valuation with (17).

Proof of Proposition 1:

The plan of the proof is the following. First, I will solve for the optimal mechanism ignoring the constraint $q'(\theta) > 0$. Second, I will prove the properties of the optimal mechanism. Third, I

will show that the solution satisfies the second order condition and the condition that $q'(\theta) > 0$ if C is low enough or if γ is not too close to either 0 or 1.

First, I start by solving for the optimal mechanism. To this end, substituting (12) into (17) and rearranging yields that the Lagrangian is:

$$L(q(\theta),\lambda) = \int_{\theta_0}^{\theta_1} \left(p(q(\theta);\theta)q(\theta) - \frac{C}{\gamma} \right) f_H(\theta)d\theta \tag{A-5}$$

$$+\lambda\left(\int_{\theta_0}^{\theta_1} \left(\left(p(q(\theta);\theta)q(\theta) - q(\theta)\frac{1-F_H(\theta)}{f_H(\theta)} \right) f_H(\theta) - \left(p(q(\theta);\theta)q(\theta) - q(\theta)\frac{1-F_L(\theta)}{f_L(\theta)} \right) f_L(\theta) \right) d\theta - \frac{C}{\gamma(1-\gamma)} \right).$$

Differentiating (A-5) with respect to $q(\theta)$ and λ and rearranging yields that $(q^{**}(\theta), T^{**}(\theta))$, and λ^{**} are the solution to:

$$q(\theta) = q^*(\theta) - \lambda \frac{F_L(\theta) - F_H(\theta)}{2\left(f_H(\theta) + \lambda(f_H(\theta) - f_L(\theta))\right)}, \tag{A-6}$$

$$E_H\left(p(q(\theta);\theta)q(\theta) - q(\theta)\frac{1-F_H(\theta)}{f_H(\theta)} \right) - E_L\left(p(q(\theta);\theta)q(\theta) - q(\theta)\frac{1-F_L(\theta)}{f_L(\theta)} \right) = \frac{C}{\gamma(1-\gamma)}, \tag{A-7}$$

$$T(\theta) = p(q(\theta);\theta)q(\theta) - \int_{\theta_0}^{\theta} q(\theta)d\theta - E_H\left(p(q(\theta);\theta)q(\theta) - q(\theta)\frac{1-F_H(\theta)}{f_H(\theta)} - \frac{C}{\gamma} \right), \tag{A-8}$$

where (A-6) and (A-7) are the first order conditions for (A-5) with respect to $q(\theta)$ and λ respectively, and (A-8) is derived using (12) and (14) in equality (notice that $U(\theta_0)$ is the last term in (A-8)). The second order condition for (A-5) with respect to $q(\theta)$ requires that $f_H(\theta) + \lambda^{**}(f_H(\theta) - f_L(\theta)) > 0$.

Next, I turn to the second part of showing the properties of the optimal solution. Let $q(\lambda;\theta)$ denotes the right hand side of (A-6) and let $T(\lambda;\theta)$ denotes the right hand side of (A-8) evaluated at $q(\lambda;\theta)$. λ^{**} is therefore the solution to

$$E_H T(\lambda;\theta) - E_L T(\lambda;\theta) = \frac{C}{\gamma(1-\gamma)}, \tag{A-9}$$

and $q^{**}(\theta) = q(\lambda^{**};\theta)$. Now, if $C = 0$, then $\lambda^{**} = 0$ and $q^{**}(\theta) = q^*(\theta)$. To see why, if $C = 0$ the right hand side of (A-9) equals to 0 and from Lemma 2, the left hand side of (A-9) equals to 0 at $q(\lambda;\theta) = q^*(\theta)$, while (A-6) shows that $q(0;\theta) = q^*(\theta)$, implying $\lambda^{**} = 0$. Next

suppose that $C/\gamma(1-\gamma) > 0$. Given that the second order condition holds, the left hand side of (A-9) is increasing with λ^{**} because

$$\frac{\partial}{\partial\lambda}\left(E_H T(\lambda;\theta) - E_L T(\lambda;\theta)\right)\Big|_{\lambda=\lambda^{**}} = \int_{\theta_0}^{\theta_1} \frac{f_H(\theta)^2 (F_H(\theta) - F_L(\theta))^2}{2\left(f_H(\theta) + \lambda^{**}(f_H(\theta) - f_L(\theta)\right)^3} d\theta > 0\,, \qquad \text{(A-10)}$$

where the inequality follows because $f_H(\theta) + \lambda^{**}(f_H(\theta) - f_L(\theta)) > 0$. Since the right hand side of (A-9) is increasing with $C/\gamma(1-\gamma)$, it follows that λ^{**} is increasing with $C/\gamma(1-\gamma)$, and $\lambda^{**} > 0$ if $C/\gamma(1-\gamma) > 0$. As for $q^{**}(\theta)$, since $\lambda^{**} > 0$, it follows from (A-6), that $q^*(\theta) - q^{**}(\theta) > (<) = 0$ if $F_L(\theta) > (<) = F_H(\theta)$ and the gap $|q^*(\theta) - q^{**}(\theta)|$ is increasing with the gap $|F_L(\theta) - F_H(\theta)|$. Moreover,

$$\frac{\partial}{\partial\lambda}(q^*(\theta) - q(\lambda;\theta))\Big|_{\lambda=\lambda^{**}} = \frac{f_H(\theta)(F_L(\theta) - F_H(\theta))}{2(f_H(\theta) + \lambda^{**}(f_H(\theta) - f_L(\theta)))^2}\,, \qquad \text{(A-11)}$$

which is positive (negative) if $F_L(\theta) > (<) F_H(\theta)$. Since λ^{**} is increasing with $C/\gamma(1-\gamma)$, the gap $|q^*(\theta) - q^{**}(\theta)|$ is increasing with $C/\gamma(1-\gamma)$. Next consider $T^{**}(\theta)$. Since $q^*(\theta) - q^{**}(\theta) > (<) = 0$, if $F_L(\theta) > (<) = F_H(\theta)$, it follows from (13) that $T'^{**}(\theta) > (<) = 0$ if $F_L(\theta) > (<) = F_H(\theta)$.

Next I turn to the third part of showing that the above solution satisfies the condition $q'^{**}(\theta) > 0$ and $f_H(\theta) + \lambda^{**}(f_H(\theta) - f_L(\theta)) > 0$ if C is low and γ is intermediate. Notice first that $q^*(\theta)$ is increasing with θ. Since $q(0;\theta) = q^*(\theta)$ and $q(\lambda;\theta)$ is continuous with λ, it follows that $q^{**}(\theta)$ is increasing with θ if λ^{**} is not too high, which in turn holds if $C/\gamma(1-\gamma)$ is not too high. Moreover, $f_H(\theta) + \lambda^{**}(f_H(\theta) - f_L(\theta)) > 0$ if $\lambda^{**} = 0$ or λ^{**} is not too high because $f_H(\theta) > 0$. Therefore, the second order condition holds if $C/\gamma(1-\gamma)$ is not too high. The exact condition on $C/\gamma(1-\gamma)$ from which on these two conditions do not hold depends on the two distribution functions.

Proof of Proposition 2:

I will prove this proposition in two steps. First, I will show that given that M accepted the contract $(S, \tilde{T}(q))$ and R placed the new product on the shelf, then given the true realization of θ, R will choose $q = q(\theta)$. Second, I will show that given the above, M will accept the contract $(S, \tilde{T}(q))$ only after testing the product and realizing that the state is H.

Starting with the first stage, recall that R's original problem given the contract ($q(\tilde{\theta})$, $T(\tilde{\theta})$) is to set $\tilde{\theta}$ as to maximize $U(\theta;\tilde{\theta})$, which yields the following first and second order conditions:

$$(\theta - 2q(\theta)) = \frac{T'(\theta)}{q'(\theta)}, \tag{A-12}$$

$$-2q'(\theta)^2 + (\theta - 2q(\theta))q''(\theta) - T''(\theta) < 0. \tag{A-13}$$

R's problem given the contract $(S, \tilde{T}(q))$ and the realization of θ is to maximize

$$\pi(q;\theta) = (\theta - q)q - \tilde{T}(q). \tag{A-14}$$

The first and second order conditions are

$$\theta - 2q = \tilde{T}'(q), \tag{A-15}$$

$$-2 - \tilde{T}''(q) < 0, \tag{A-16}$$

where the left hand side in (A-15) is R's marginal revenue and the right hand side in (A-15) is R's marginal cost. From (14),

$$\tilde{T}'(q) = \frac{T'(\theta)}{q'(\theta)}, \tag{A-17}$$

$$\tilde{T}''(q) = \frac{\partial}{\partial\theta}\left(\frac{T'(\theta)}{q'(\theta)}\right)\Big/ q'(\theta) = \frac{T''(\theta)q'(\theta) - T'(\theta)q''(\theta)}{q'(\theta)^3}. \tag{A-18}$$

Substituting (13) into (A-17) and recalling that $q^{**}(\theta) < q^{*}(\theta)$, $\tilde{T}(q)$ is increasing in q, implying that R will always sell to consumers all the quantity it chooses to buy from M. Let $q^{**}(\theta)$ denote the solution to (A-15), given θ. Substituting (A-17) into (A-15) yields

$$\theta - 2q^{**}(\theta) = \frac{T'(\theta)}{q'(\theta)}. \tag{A-19}$$

Comparing (A-19) with (A-12) yields that $q^{**}(\theta) = q(\theta)$. To see that the second order conditions are satisfied, substituting (A-12) into (A-13) and rearranging yields

$$-2 - \frac{T''(\theta)q'(\theta) - T'(\theta)q''(\theta)}{q'(\theta)^3} < 0. \tag{A-20}$$

Substituting (A-18) into (A-16) yields an identical condition. Since the first and second order conditions given the contract ($q(\theta)$,$T(\theta)$) are satisfied, they are also satisfied given the contract (S, $\tilde{T}(q)$). Turing to the first step, by accepting the contract (S, $\tilde{T}(q)$) M earns ex-ante expected profit: $T(\theta_0) + E_k\tilde{T}(q) = T(\theta_0) + E_k\{-T(\theta_0) + T(\theta)\} = E_kT(\theta)$, k = H, L, which is identical to M's expected profit from accepting the contract ($q(\theta)$,$T(\theta)$), hence the two problems are equivalent.

Proof of Proposition 3:

Suppose first that $\pi^* > \gamma E_H\pi^*(\theta) + (1 - \gamma)E_L\pi^*(\theta)$, such that if R chooses not to use the mechanism, R prefers to sell the old product. In this case R will use the mechanism if

$$-C + \gamma E_H\pi^{**}(\theta) + (1 - \gamma)\pi^* \geq \pi^*. \tag{A-21}$$

From Proposition 1, the gap $|q^*(\theta) - q^{**}(\theta)|$ is increasing with C and equals to zero for $C = 0$. Therefore, $\pi^{**}(\theta)$ is decreasing with C and equals to $\pi^*(\theta)$ for $C = 0$. Thus the left hand side of (A-21) is decreasing with C, and the inequality holds for $C < C^{**}$, where C^{**} is the solution to

$$C^{**} = \gamma(E_H\pi^{**}(\theta) - \pi^*). \tag{A-22}$$

Since $\pi^{**}(\theta) < \pi^*(\theta)$ for $C > 0$, the right hand side in (A-22) is lower than the term in the first line in (4), implying that $C^{**} < C^*$. Also, if $C = 0$, (A-21) always hold because $\pi^{**}(\theta) = \pi^*(\theta)$ and by assumption, $E_H\pi^*(\theta) > \pi^*$. Next suppose that $\pi^* < \gamma E_H\pi^*(\theta) + (1 - \gamma)E_L\pi^*(\theta)$, such that if R chooses not to use the mechanism, R prefers to sell the new product. In this case R will use the mechanism if

$$-C + \gamma E_H\pi^{**}(\theta) + (1 - \gamma)\pi^* \geq \gamma E_H\pi^*(\theta) + (1 - \gamma)E_L\pi^*(\theta). \tag{A-23}$$

Since $\pi^{**}(\theta)$ is decreasing with C, the left hand side of (A-23) is decreasing with C, implying that R will use the mechanism if $C < C^{**}$, where C^{**} is the solution to:

$$C^{**} = (1 - \gamma)(\pi^* - E_L\pi^*(\theta)) - \gamma E_H(\pi^*(\theta) - \pi^{**}(\theta)). \tag{A-24}$$

Since $\pi^{**}(\theta) < \pi^*(\theta)$ for $C > 0$, the right hand side of (A-24) is lower than the second line in (4), implying that $C^{**} < C^*$. Also, if $C = 0$, (A-23) always hold because $\pi^{**}(\theta) = \pi^*(\theta)$ and by assumption, $E_L\pi^*(\theta) < \pi^*$.

A proof that IC_R holds for the numerical simulation in Section 5:

In this proof I show that the numerical example in Section 5 satisfies global IC_R. That is, the proof of Lemma 1 already ensures local IC_R in that if $\theta\in[0, 1/2]$ ($\theta\in[1/2, 1]$), R will not report any $\tilde{\theta}\in[0, 1/2]$ ($\tilde{\theta}\in[1/2, 1]$). This follows from Lemma 1 because in the numerical simulation $q^{**}(\theta)$ is continuous and increasing with θ for $\theta\in[0, 1/2]$ and $\theta\in[1/2, 1]$. However, because $q^{**}(\theta)$ in the numerical example is not continuous in $\theta = 1/2$, I need to show that given that $\theta\in[0, 1/2]$ ($\theta\in[1/2, 1]$), R will not report any $\tilde{\theta}\in[1/2, 1]$ ($\tilde{\theta}\in[0, 1/2]$). To this end, substituting (19) and (20) into (A-6), reveals that:

$$q(\lambda;\theta) = \begin{cases} \dfrac{1-\lambda}{2-\lambda}\theta, & \theta\in[0,\tfrac{1}{2}], \\ \dfrac{\lambda(2\theta-1)+3\theta}{6+2\lambda}, & \theta\in[\tfrac{1}{2},1]. \end{cases} \tag{A-25}$$

It is easy to see that $q(\lambda;\theta)$ is positive and increasing with θ if $0 < \lambda < 1$, which, as the numerical simulation reveals, occurs for $0 < C < 0.00358$. Let $U_1(\theta;\tilde{\theta})$ and $U_2(\theta;\tilde{\theta})$ denotes (A-2), evaluated at the first and the second lines of (A-25). Straightforward calculations reveal that:

$$U_1(\theta;\tfrac{1}{2}) - U_2(\theta;\tfrac{1}{2}) = \left[\frac{\lambda(1+2\lambda)}{8(6-\lambda-\lambda^2)}\right](1-2\theta)\,, \tag{A-26}$$

where the term inside the squared brackets is always positive because $0 < \lambda < 1$, and (A-26) is positive (negative) if $\theta < (>)\ 1/2$.

Now, suppose that $\theta\in[0, 1/2]$. If R reports $\tilde{\theta}\in[1/2, 1]$ then $U(\theta) > U_1(\theta;1/2) > U_2(\theta;1/2) > U(\theta;\tilde{\theta})$, where the first inequality follows from Lemma 1, the second inequality follows because (A-26) is positive at $\theta < 1/2$, and the third inequality follows from Lemma 1. Therefore, R prefers to report $\tilde{\theta} = \theta$. Likewise, suppose that $\theta\in[1/2, 1]$. If R reports $\tilde{\theta}\in[0, 1/2]$, then $U(\theta) > U_2(\theta;1/2) > U_1(\theta;1/2) > U(\theta;\tilde{\theta})$, where the first inequality follows from Lemma 1, the second inequality follows because (A-26) is negative at $\theta > 1/2$, and the third inequality follows form Lemma 1. Therefore, R prefers to report $\tilde{\theta} = \theta$.

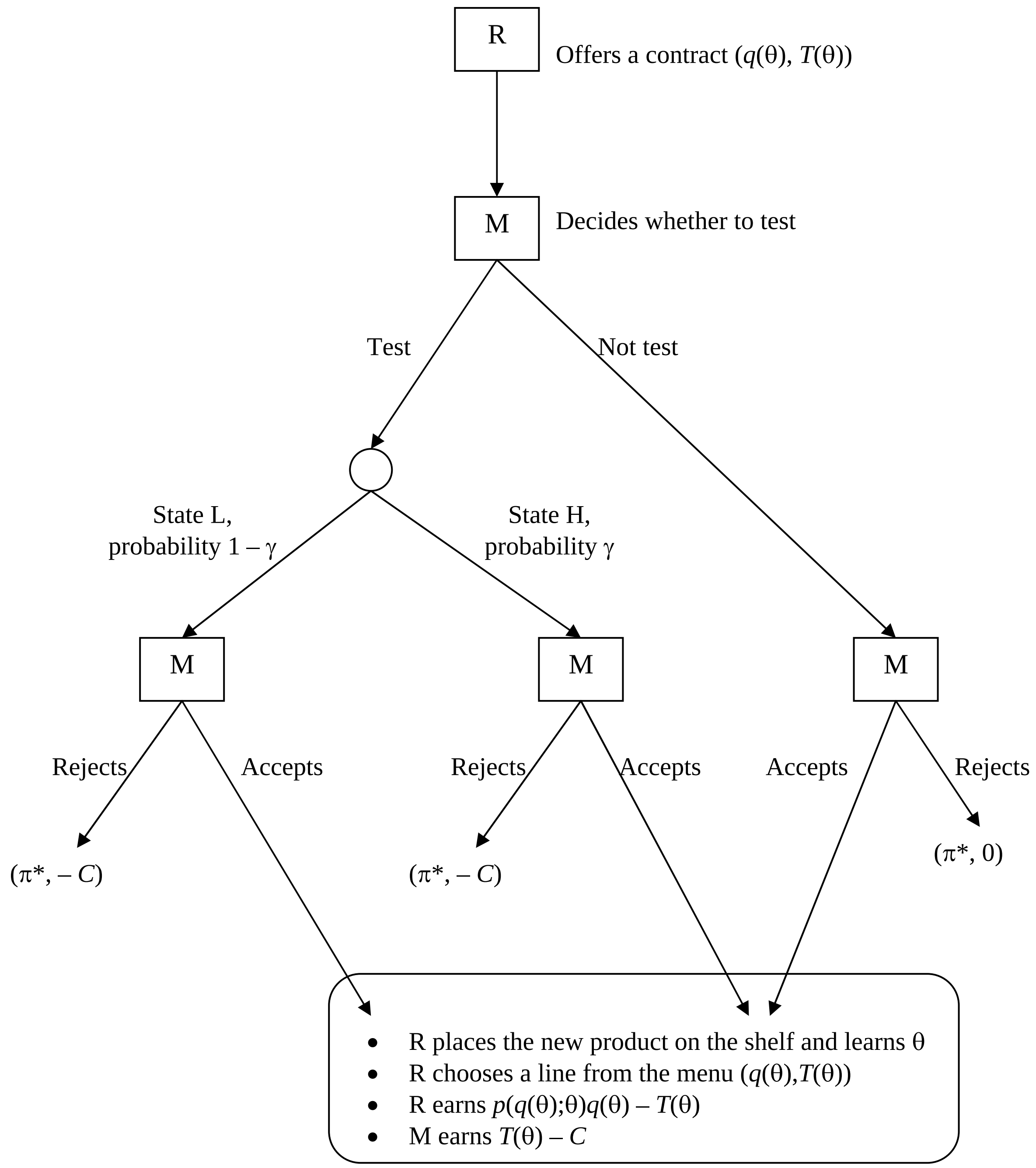


Figure 1: The timing of the game

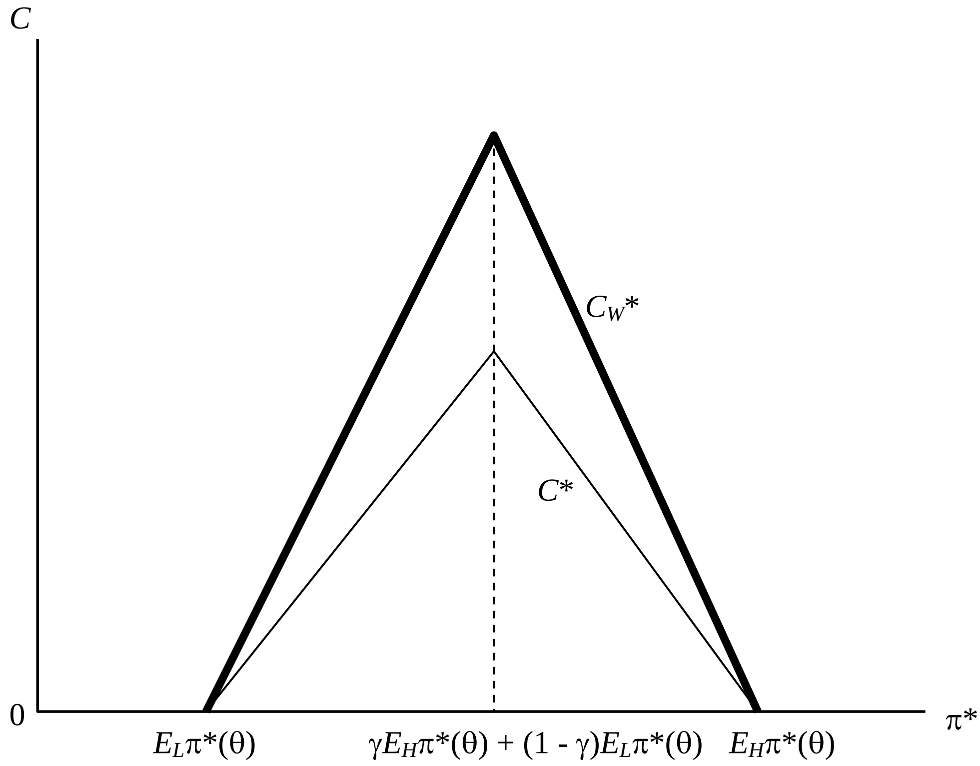
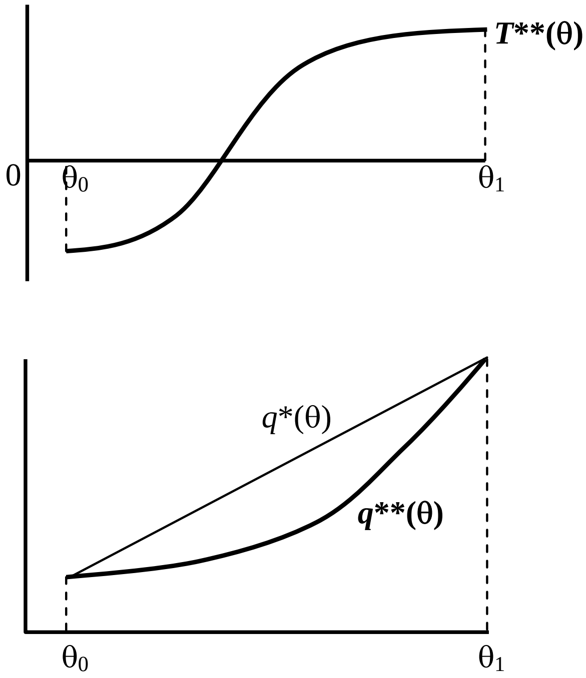
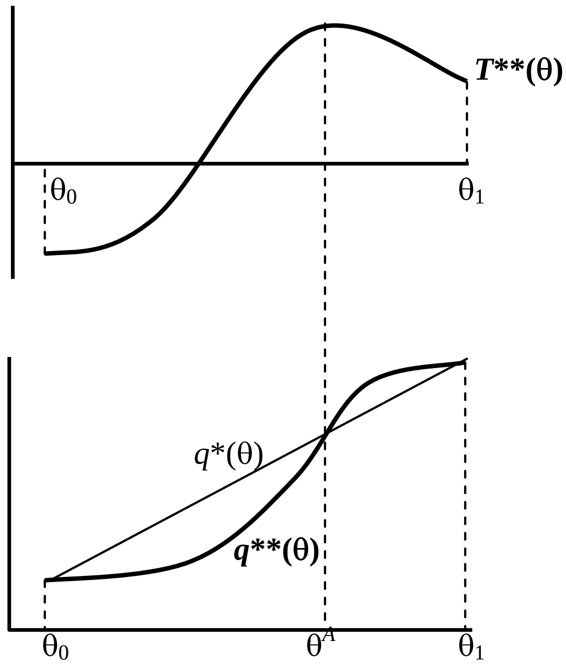
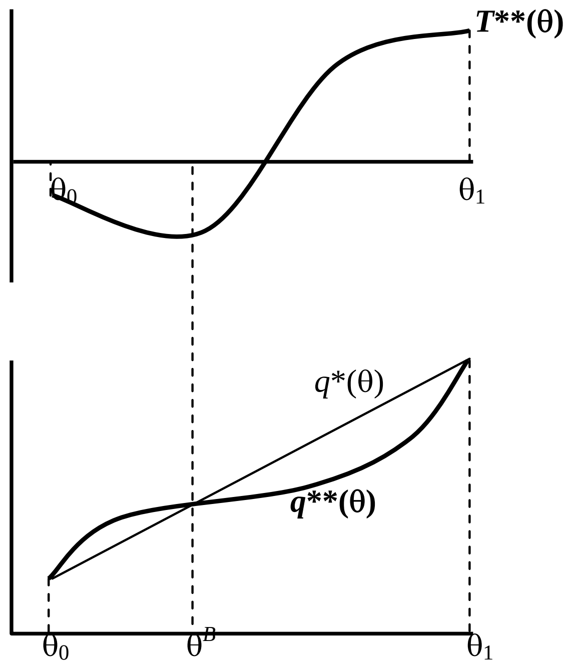


Figure 2: The cutoff values C^* and C_W^* as a function of π^*



Panel (a): $F_L(\theta) > F_H(\theta)\ \ \forall\theta\in[\theta_0, \theta_1]$

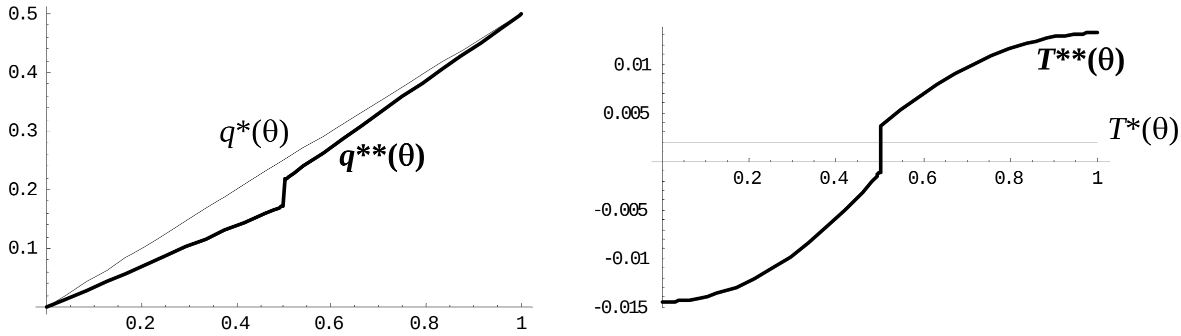




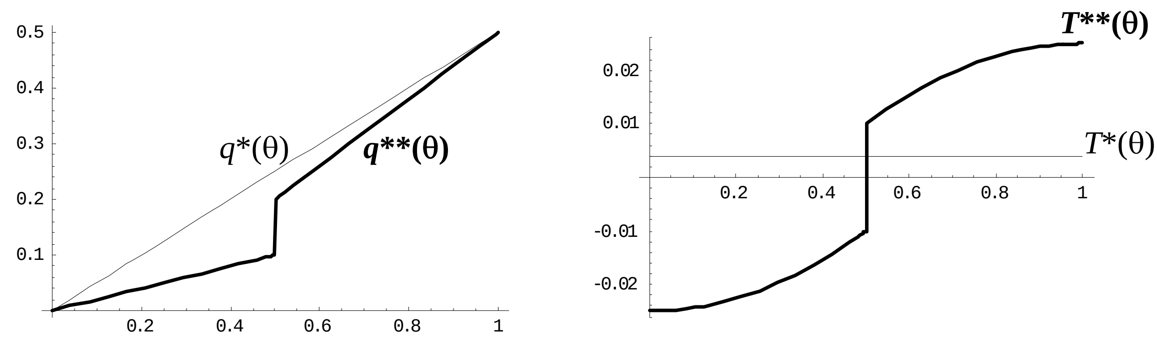
Panel (b): $F_L(\theta) > F_H(\theta)\ \ \forall\theta\in[\theta_0, \theta^A]$,
$F_L(\theta) < F_H(\theta)\ \ \forall\theta\in[\theta^A, \theta_1]$

Panel (c): $F_L(\theta) < F_H(\theta)\ \ \forall\theta\in[\theta_0, \theta^B]$,
$F_L(\theta) > F_H(\theta)\ \ \forall\theta\in[\theta^B, \theta_1]$

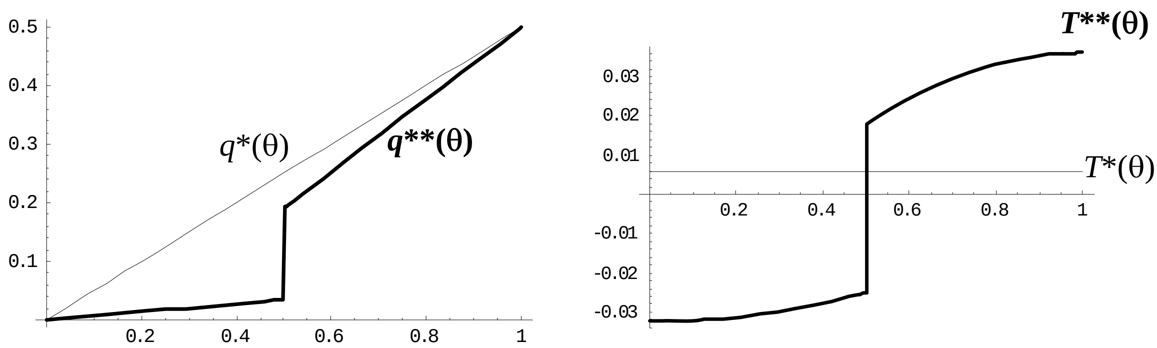
Figure 3: The optimal mechanism under asymmetric information



Case 1: *C* = 0.001



Case 2: *C* = 0.002



Case 3: *C* = 0.003

Figure 4: The optimal mechanism for selected values of *C*

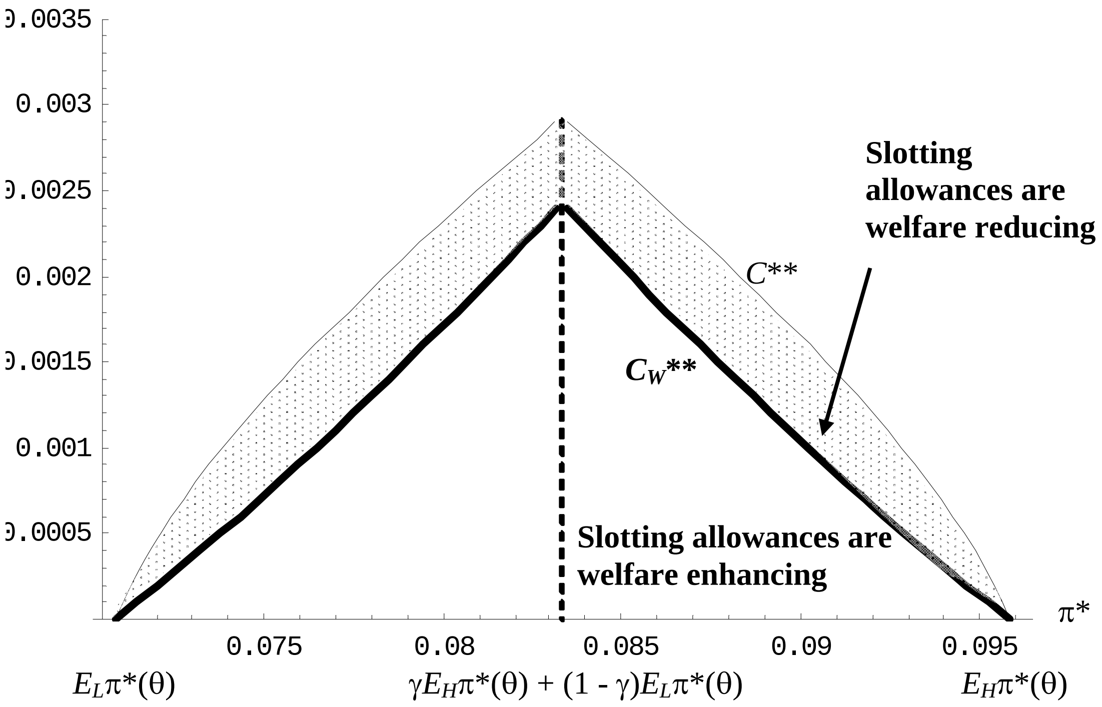


Figure 5: The cutoffs C^{**} and C_W^{**} under asymmetric information

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