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Schmitz, Patrick W.

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Monopolistic licensing strategies under asymmetric information[1]

Patrick W. Schmitz

University of Bonn, Adenauerallee 24-42,

53113 Bonn, Germany

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Abstract

Consider a research lab that owns a patent on a new technology but cannot develop a marketable final product based on the new technology. There are two downstream firms that might successfully develop the new product. If the downstream firms' benefits from being the sole supplier of the new product are private information, the research lab will sometimes sell two licences, even though under complete information it would have sold one exclusive licence. This is in contrast to the standard result that a monopolist will sometimes serve less, but never more buyers when there is private information.

Journal of Economic Literature Classification Numbers: L12, D45, D82

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1 Introduction

Consider a research lab that has patented a new technology and is thus in a monopolistic situation. It is specialized in basic research and does not have the ability to develop and produce a marketable final product that is based on the new technology. However, there are two downstream firms that have such abilities. Each of these downstream firms could with a certain probability be successful in developing the new product, provided it gets a license from the monopolist. A downstream firm enjoys a private benefit if it is the sole supplier of the new product. However, if the monopolist sells licences to both firms, then both may successfully develop the new product, in which case they enjoy no benefits due to competition. Hence, the monopolist may be able to achieve a higher revenue if he or she sells an exclusive licence to one downstream firm only.

The problem of a monopolistic research lab that can license an innovation to firms that are competitors in a downstream market has received considerable attention in the literature.[1] Following Katz and Shapiro [15], it is assumed here that each downstream firm has use for only one unit of the input (only one licence for a given patent) and that the upstream monopolist can provide the input at zero cost (i.e., the costs of making the innovation have already been expended). Yet, Katz and Shapiro [15] assume that the downstream firms are identical and that there is complete information. In contrast, in the present paper the downstream firms do not need to be identical and the focus is on the effects of the downstream firms' private information about their benefits.[2]

[1] For example, see Kamien and Tauman [10, 11], Katz and Shapiro [14, 15], Kamien, Tauman, and Zang [13], Rockett [25], Kamien, Oren, and Tauman [12], and Bousquet, Cremer, Ivaldi, and Wolkowicz [2]. For surveys, see Reinganum [23] and Kamien [9].

[2] Given the fact that there is a large literature on licensing, it is surprising that almost all papers in this literature assume complete information. Two exceptions are Gallini and Wright [5] and Beggs [1]. However, the focus of these papers is quite different. In

The effects of introducing private information about the buyers' valuations in models of monopolistic supply of (private or public) goods are by now well understood.[3] In accordance with this literature it turns out that the monopolist will sometimes sell no licence at all, which would never happen under complete information. However, the peculiar economics of selling licences lead to an interesting conclusion that is in contrast to the standard results on profit-maximizing mechanisms under private information. It will be demonstrated that there are circumstances under which a monopolist sells two licences under private information, while he or she would have sold an exclusive licence to one firm under complete information. This is interesting since usually private information distorts the number of buyers served downwards, but not upwards.[4]

Intuitively, the reason is as follows. Consider a monopolist who sells a usual private good to two potential buyers with unit demand. The monopolist wants the buyers to reveal their valuations. However, a buyer with a high valuation is tempted to claim that his or her valuation is low in order to reduce the payment he or she has to make. Therefore, the monopolist threatens to reduce the quantity that a buyer can expect to receive when he or she announces a low valuation. Such a reduction hurts a buyer with a high valuation more than a buyer with a low valuation, so that truthful revela-

particular, they analyze signaling models, while the present paper studies an adverse selection problem.

[3] See, for instance, the survey of Fudenberg and Tirole [4, chapter 7] and the literature cited there.

[4] See Myerson [20] and Bulow and Roberts [3] for the case of a monopolist selling private goods, Güth and Hellwig [6] and Rob [24] for monopolistic supply of public goods, and Schmitz [26] for monopolistic provision of excludable public goods. Moreover, note that in the case of bilateral trading analyzed by Myerson and Satterthwaite [22], inefficiency only arises because there are situations where under complete information trade *would* occur, but the good is *not* traded under asymmetric information. See McKelvey and Page [17] for results regarding the direction of inefficiency in bilateral bargaining over trade of a divisible good.

tion can be induced.[5] In contrast, when selling licences, the monopolist can induce truthful revelation not only by threatening to reduce the probability that a buyer who claims to have a low valuation receives a license, but also by the threat of selling a licence to the other buyer, too. Hence, in some states of the world private information can lead to an increase in the number of licenses sold.

To the best of my knowledge, this is the first paper which shows that private information can distort the number of buyers that are served by a monopolist *upwards*, provided that the reservation utilities are exogenously given. It is by now well known that upward distortions of the quantity traded can occur if reservation utilities are type-dependent. This follows from Lewis and Sappington's [16] seminal paper on countervailing incentives.[6] However, in contrast to this literature and in accordance with the standard adverse selection models, in the present paper a buyer's utility net of his or her reservation utility is always increasing in his or her type, independent of the quantity sold. A main finding of Jehiel, Moldovanu and Stacchetti [7] is that in their model (where the seller has only one object) under asymmetric information a sale may occur even if efficiency requires that the good stays with the seller. While they assume that there are multi-dimensional types and that reservation utilities are endogenous and type-dependent, the present paper demonstrates that no such assumptions are necessary in order

[5] Notice that if the monopolist has only one good to sell, a reduction of the quantity that a buyer expects to receive can also be achieved if the good is given to the other buyer. When the distributions of the buyers' valuations are not identical, it may thus happen that under private information buyer 1 receives the good, while under symmetric information buyer 2 would get the good (see Myerson [20]). Hence, the quantity received by buyer 1 is distorted upwards. However, it is always true that there is no state of the world in which the monopolist sells more under private information than he or she would sell under symmetric information.

[6] See Jullien [8] for a comprehensive analysis of principal-agent problems with type-dependent reservation utilities.

to create an upward distortion in the number of sales. Segal [27] discusses a general (complete information) model of contracting with externalities. In his wording, the model of Jehiel, Moldovanu and Stacchetti [7] depends on "externalities on non-traders", while there are no such externalities in the present paper.

As an illustration, imagine that the new technology patented by the monopolist might be the basis for developing a new medicament against a disease that so far could not be cured (or that could only be treated with medicine that is supplied competitively). In this case it makes sense to assume that if only one firm gets a license or is successful in developing the new product, there are no external effects on the other firm.[7]

The remainder of the paper is organized as follows. In the following section, the basic model is introduced and the complete information benchmark case is analyzed. In Section 3, private information is introduced and the main result is derived. Concluding remarks follow in Section 4. Some technical details have been relegated to the appendix.

2 The model

Consider a monopolist who can sell licences to two potential buyers (downstream firms). If downstream firm $i \in \{1, 2\}$ gets an exclusive licence, it can develop a marketable final product with probability $p_i \in (0, 1)$, so that its profits are given by $p_i B_i - t_i$, where B_i are the benefits from being the sole supplier of the final product and t_i denotes the payment to the monopolist. If the monopolist sells licences to both buyers, then the profits of firm i are given by $p_i(1 - p_j)B_i - t_i$, with $j \neq i$. Hence, if both downstream firms are successful in developing the final product (which happens with probability

[7] Moreover, note that it may well be that there is only a small number of pharmaceutical firms that have the know-how and the capacities to develop the new product, and the potential licensees may well be known to have different probabilities of success.

$p_i p_j$), there are no benefits from being the sole supplier of the new product.[8]

Assume that $B_1 \in [0, \overline{B}_1]$ and $B_2 \in [0, \overline{B}_2]$ are independently distributed random variables and that the distribution functions F_i are continuously differentiable. Denote the corresponding density functions by f_i. Let $q^i \in [0,1]$ denote the probability that buyer i gets an exclusive licence, and let $q^{12} \in [0,1]$ be the probability that both buyers each get a licence. Obviously, $0 \leq q^1 + q^2 + q^{12} \leq 1$ must hold. Firm i's payoff is hence given by

$$u_i = q^i p_i B_i + q^{12}(1 - p_j) p_i B_i - t_i.$$

Following the mechanism design literature, it is assumed that the monopolist has full bargaining and commitment power, so that he or she can make a take-it-or-leave-it offer to the downstream firms. The firms can then accept or reject the monopolist's offer. If a firm rejects the offer, the parties receive their reservation utilities which are normalized to zero. Otherwise, the licences are provided and payments are made according to the mechanism.

As a benchmark, consider first the case of complete information. The following proposition characterizes the monopolist's optimal licencing strategy, i.e. the profit-maximizing choice of $q = (q^1, q^2, q^{12})$ depending upon the realizations of B_1 and B_2.

Proposition 1 *The monopolist's optimal licencing strategy under complete information is given by*

$$q = \begin{cases} (1,0,0) & \textit{if } B_2 < B_1 \min\left\{\frac{p_1}{p_2}, \frac{p_1}{1-p_1}\right\}, \\ (0,1,0) & \textit{if } B_2 > B_1 \max\left\{\frac{p_1}{p_2}, \frac{1-p_2}{p_2}\right\}, \\ (0,0,1) & \textit{otherwise.} \end{cases}$$

Proof. The monopolist maximizes his or her profits $t_1 + t_2$ subject to the firms' participation constraints $u_i \geq 0, i \in \{1,2\}$, and $0 \leq q^1 + q^2 + q^{12} \leq 1$.

[8] The structure of the payoffs has been chosen to be as simple as possible. Of course, the case in which the downstream firms' willingness-to-pay for a license depends on additional profits that are verifiable could be dealt with in a straightforward way.

The participation constraints must hold with equality, since the monopolist would increase t_i if $u_i > 0$. Hence, $t_i = q^i p_i B_i + q^{12}(1-p_j)p_i B_i$, so that the monopolist maximizes

$$\begin{aligned} & \sum_{i=1}^{2} \left(q^i p_i B_i + q^{12}(1-p_j)p_i B_i\right) \\ = \; & q^1 p_1 B_1 + q^2 p_2 B_2 + q^{12}\left[(1-p_2)p_1 B_1 + (1-p_1)p_2 B_2\right] \end{aligned}$$

subject to $0 \leq q^1 + q^2 + q^{12} \leq 1$. It is straightforward to verify that this expression is maximized by q as characterized in the proposition. For instance, if $p_2 B_2 > p_1 B_1$ and $p_2 B_2 > (1-p_2)p_1 B_1 + (1-p_1)p_2 B_2$, so that $B_2 > \max\{\frac{p_1}{p_2}B_1, \frac{1-p_2}{p_2}B_1\}$, then $q^2 = 1$ is optimal. The other cases follow in an analogous way. Finally, notice that the transfer payments t_i can easily be calculated using the binding participation constraints $u_i = 0$. ■

In the case of complete information, the monopolist can extract the total gains from trade.[9] A downstream firm gets an exclusive license if its benefit from being the sole supplier of the new product is sufficiently larger than the other firm's benefit. Moreover, ceteris paribus a firm gets a license in more states of the world if its probability of success is increased. Notice that the monopolist will never give both downstream firms licences if $p_1 + p_2 > 1$.[10]

As an illustration of the optimal mechanism, consider the example displayed in Figure 1.[11] The figure shows which firm gets a licence in the case $p_1 = \frac{1}{2}$ and $p_2 = \frac{2}{5}$ for all possible realizations of B_1 and B_2, when $\overline{B}_1 = \overline{B}_2 = 1$.

[9] Note that the monopolist could also extract the total gains from trade if only the downstream firms were symmetrically informed, but the monopolist did not know the firms' willingness-to-pay. This follows from the literature on (subgame perfect) Nash implementation, see Moore and Repullo [19] and Moore [18].

[10] This is a straightforward generalization of the obvious fact that a monopolist will never sell more than one license to Bertrand competitors if there is no further development stage (i.e., if $p_1 = p_2 = 1$). See e.g. Kamien [9].

[11] In the figure, (1) means that buyer 1 gets an exclusive license, (2) means that buyer 2 gets an exclusive license, and (12) means that both buyers get a license each.

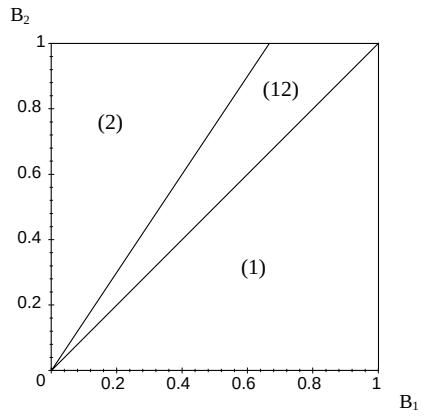

Figure 1. Optimal licensing strategy under complete information.

3 Private information

Now assume that the realizations of B_1 and B_2 are private information of the downstream firms 1 and 2, respectively. According to the revelation principle (see e.g. Myerson [21]), the monopolist can confine his or her search for an optimal mechanism to the class of direct revelation mechanisms. A direct mechanism $(q(B), t_1(B), t_2(B))$ determines the licencing decisions and the transfer payments as functions of the firms' reports about their benefits $B = (B_1, B_2)$. The mechanism must be constructed so that in equilibrium the firms are induced to reveal their private information truthfully. Following most of the Bayesian mechanism design literature, attention will be confined to what Myerson [20] called the regular case, i.e. it will be assumed that the so-called virtual benefit $v_i(B_i) = B_i - \frac{1-F_i(B_i)}{f_i(B_i)}$ is monotonically increasing.[12]

[12] Note that it is sufficient that the well-known monotone hazard rate condition $\frac{d}{dB_i}\frac{1-F_i}{f_i} < 0$ holds. See e.g. Fudenberg and Tirole [4, chapter 7] and the literature discussed there.

Proposition 2 *In the case of private information, it is optimal for the monopolist to choose the following licensing strategy:*

$$q = \begin{cases} (0,0,0) & \textit{if } \max\{v_1(B_1), v_2(B_2)\} < 0 \\ (1,0,0) & \textit{if } \max\{v_2(B_2), 0\} < v_1(B_1) \min\left\{\frac{p_1}{p_2}, \frac{p_1}{1-p_1}\right\} \\ (0,1,0) & \textit{if } v_2(B_2) > \max\{v_1(B_1), 0\} \max\left\{\frac{p_1}{p_2}, \frac{1-p_2}{p_2}\right\} \\ (0,0,1) & \textit{otherwise} \end{cases}$$

Proof. Define $q_i = q^i + (1-p_j)q^{12}$, where $i, j \in \{1,2\}, i \neq j$. Firm i's (interim) expected payoff can then be written as

$$U_i(B_i) = E_j\left[q_i(B)p_iB_i - t_i(B)\right],$$

where E_j denotes the expectation operator with respect to B_j. The monopolist maximizes his or her expected profits $E(t_1 + t_2)$ subject to the firms' (interim) participation constraints $U_i(B_i) \geq 0, \forall i, \forall B_i$, the firms' Bayesian incentive compatibility constraints

$$U_i(B_i) \geq E_j\left[q_i(\tilde{B}_i, B_j)p_iB_i - t_i(\tilde{B}_i, B_j)\right]$$

$\forall i, \forall B_i, \forall \tilde{B}_i$, and $0 \leq q^1 + q^2 + q^{12} \leq 1$. The incentive compatibility constraints mean that it is rational for firm i to reveal its private information truthfully given that firm $j \neq i$ tells the truth.

The following lemma is a straightforward application of standard Bayesian mechanism design techniques and is proved in the appendix.

Lemma 1 *The mechanism $(q(B), t_1(B), t_2(B))$ is Bayesian incentive compatible if and only if $E_j(q_i(B))$ is non-decreasing in B_i and firm i's (interim) expected payoff satisfies $U_i(B_i) = U_i(0) + \int_0^{B_i} p_iE_j\left[q_i(\check{B}_i, B_j)\right] d\check{B}_i$.*

Given incentive compatibility, firm i's expected payment hence satisfies

$$\begin{aligned} E[t_i] &= E\left[q_i(B)p_iB_i - U_i(B_i)\right] \\ &= E\left[q_i(B)p_iB_i - \int_0^{B_i} p_iE_j\left[q_i(\check{B}_i, B_j)\right] d\check{B}_i\right] - U_i(0) \\ &= E\left[q_i(B)p_i\left(B_i - \frac{1-F_i(B_i)}{f_i(B_i)}\right)\right] - U_i(0), \end{aligned}$$

where the last line follows from partial integration. By Lemma 1, firm i's participation constraint is satisfied whenever $U_i(0) \geq 0$ holds. Hence, the monopolist will set $U_i(0) = -E[t_i(0, B_j)] = 0$, so that his or her total expected profits (using the definition of q_i) are given by

$$E\left[\sum_{i=1}^{2}\left(q^i + (1-p_j)q^{12}\right)p_i v_i(B_i)\right].$$

The monopolist chooses q such that this expression is maximized, subject to $0 \leq q^1+q^2+q^{12} \leq 1$ and the constraint that $E_j(q_i(B))$ is non-decreasing in B_i. Ignoring the monotonicity constraint, it is straightforward to verify that the licensing rule q characterized in the proposition maximizes the monopolist's expected profits. In particular, if $v_1(B_1) < 0$ and $v_2(B_2) < 0$ it is obviously optimal to choose $q^1 = q^2 = q^{12} = 0$. Moreover, $q^1 = 1$ is optimal if either $v_2(B_2) < 0 < v_1(B_1)$ or else if $p_1 v_1(B_1) > p_2 v_2(B_2) > 0$ and $p_1 v_1(B_1) > (1 - p_2)p_1 v_1(B_1) + (1-p_1)p_2 v_2(B_2)$. The other cases can be handled analogously. Next, it must be checked that the omitted monotonicity constraint is satisfied. This is the case, since by assumption $v_i(B_i)$ is increasing and hence, when B_i is increased, then $q_i(B)$ can never decrease (it can increase from 0 to 1 or from 0 to $1 - p_j$ to 1). Finally, note that only the expected transfer payments $E_j(t_i)$ are determined by Lemma 1. The actual payments could e.g. be chosen such that

$$t_i = q_i(B)p_i B_i - \int_0^{B_i} p_i q_i(\check{B}_i, B_j)d\check{B}_i.$$

■

Notice that in the proof of Proposition 2, the transfer payments t_i have been determined such that a downstream firm only has to make a payment if it actually gets a licence, which seems to be plausible. Obviously, under incomplete information the monopolist can no longer extract the total surplus. Furthermore, notice that (as was the case under complete information) the monopolist never sells licences to both firms if $p_1 + p_2 > 1$.

As an illustration, consider again the example of the previous section, where $p_1 = \frac{1}{2}$ and $p_2 = \frac{2}{5}$. Assume that $F_1(B_1) = B_1$ and $F_2(B_2) = 2B_2 - B_2^2$. The optimal licensing decisions of the monopolist are illustrated in Figure 2.[13]

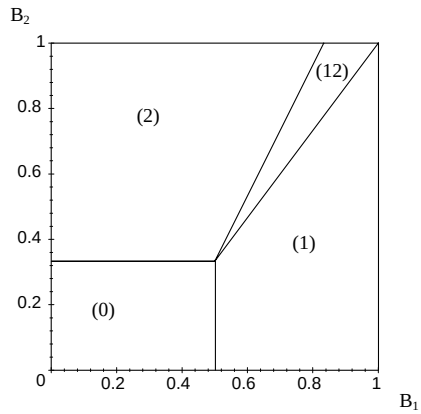

Figure 2. Optimal licensing strategy under incomplete information.

It is interesting to compare now the optimal licensing strategies under complete and under incomplete information. Consider Figure 3, which merges Figures 1 and 2. Notice that in regions A, C, and E the same licensing decisions are made in both scenarios. Moreover, there are regions (F, G, H) in which one or two licences would be sold under complete information, but no licence is sold under incomplete information. There are also circumstances in which one firm would be served under complete information, while another firm is served under incomplete information (region I), and where private information leads to the trade of one exclusive licence instead of two licences (region B). These conclusions are well in line with standard results on the effects of introducing private information in monopolistic pricing problems.

[13] In the figure, (0) means that no license is sold.

However, the economics of selling licences can also lead to an interesting conclusion that is in contrast to the usual results: In region D only firm 1 would get a licence under complete information, while both firms get a licence under incomplete information. Hence, there are situations in which *more* licences are sold due to private information. Intuitively, a buyer can as usual be deterred from understating his or her willingness-to-pay by the threat of a lower probability of getting the good. In the present context, however, the threat may also take the form of not getting an *exclusive* licence (but still one of two licences sold). The threat that the other firm also gets a license is again more harmful for a firm with a high benefit, because such a firm has to lose more. As usual, even though the monopolist would prefer not to do so once he or she knows the buyers' types, in order to be effective the threat must actually be executed in some states of the world.

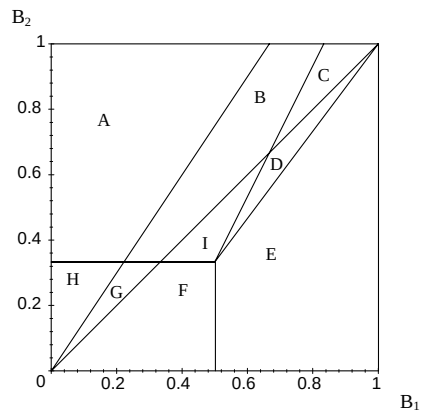

Figure 3. In region D *more* licences are sold under incomplete information.

Hence, the following result has been demonstrated.

Corollary 1 *In some states of the world, it can be optimal for the monopolist to sell two licenses in the presence of private information, while he or she would sell only one license under complete information.*

4 Conclusion

It has been shown that a profit-maximizing monopolist may sell more licenses under asymmetric information than he or she would sell under complete information. This result is in stark contrast to the standard result saying that in traditional models of adverse selection the quantity sold is always distorted downwards. Moreover, in contrast to some related findings in the recent literature and in accordance with the standard model, the upward distortion has been derived here in a model in which reservation utilities are exogenously given.

The model has been kept as simple as is consistent with making the main point. It is obvious that the model could be generalized to more than two downstream firms in a straightforward way. A somewhat more interesting generalization might be the introduction of additional private information regarding the success probabilities. Another possible extension could be the consideration of less sharp competition, so that a success is still beneficial for a firm even if it is it not the sole supplier of the new product. While such extensions would certainly complicate the exposition and might veil the simple intuition underlying the basic insight, the main effect highlighted in this paper should still continue to be relevant.

Appendix

Proof of Lemma 1.

"Only if": The incentive compatibility conditions can be written as

$$\begin{aligned} U_i(B_i) &= E_j\left[q_i(B)p_iB_i - t_i(B)\right] \geq E_j\left[q_i(\tilde{B}_i, B_j)p_iB_i - t_i(\tilde{B}_i, B_j)\right], \\ U_i(\tilde{B}_i) &= E_j\left[q_i(\tilde{B}_i, B_j)p_i\tilde{B}_i - t_i(\tilde{B}_i, B_j)\right] \geq E_j\left[q_i(B)p_i\tilde{B}_i - t_i(B)\right], \end{aligned}$$

which implies

$$E_j\left[q_i(B)p_i\right]\left(B_i - \tilde{B}_i\right) \geq U_i(B_i) - U_i(\tilde{B}_i) \geq E_j\left[q_i(\tilde{B}_i, B_j)p_i\right]\left(B_i - \tilde{B}_i\right).$$

Hence, $E_j\left[q_i(B)\right]\left(B_i - \tilde{B}_i\right) \geq E_j\left[q_i(\tilde{B}_i, B_j)\right]\left(B_i - \tilde{B}_i\right)$, so that $E_j\left[q_i(B)\right]$ must be non-decreasing in B_i. Moreover, assume w.l.o.g. that $B_i > \tilde{B}_i$, divide the chain of inequalities by $B_i - \tilde{B}_i$, and let $\tilde{B}_i$ converge to B_i in order to see that $U_i'(B_i) = E_j\left[q_i(B)p_i\right]$ almost everywhere. Hence,

$$U_i(B_i) = U_i(0) + \int_0^{B_i} p_iE_j\left[q_i(\check{B}_i, B_j)\right] d\check{B}_i.$$

"If": It has to be shown that

$$\Delta(B_i) = U_i(B_i) - E_j\left[q_i(\tilde{B}_i, B_j)p_iB_i - t_i(\tilde{B}_i, B_j)\right] \geq 0.$$

Using

$$U_i(B_i) = U_i(\tilde{B}_i) + \int_{\tilde{B}_i}^{B_i} p_iE_j\left[q_i(\check{B}_i, B_j)\right] d\check{B}_i$$

and $E_j\left[t_i(\tilde{B}_i, B_j)\right] = E_j\left[q_i(\tilde{B}_i, B_j)p_i\tilde{B}_i\right] - U_i(\tilde{B}_i)$, it is straightforward to see that

$$\begin{aligned} \Delta(B_i) &= E_j\left[q_i(\tilde{B}_i, B_j)\right]p_i\left(\tilde{B}_i - B_i\right) + \int_{\tilde{B}_i}^{B_i} p_iE_j\left[q_i(\check{B}_i, B_j)\right] d\check{B}_i \\ &= p_iB_i\left(E_j\left[q_i(B)\right] - E_j\left[q_i(\tilde{B}_i, B_j)\right]\right) \\ &\quad - \int_{\tilde{B}_i}^{B_i} p_i\check{B}_i\left(\frac{d}{d\check{B}_i}E_j\left[q_i(\check{B}_i, B_j)\right]\right) d\check{B}_i \\ &= \int_{\tilde{B}_i}^{B_i} p_i(B_i - \check{B}_i)\left(\frac{d}{d\check{B}_i}E_j\left[q_i(\check{B}_i, B_j)\right]\right) d\check{B}_i \geq 0. \end{aligned}$$

The inequality follows since $E_j\left[q_i(\check{B}_i, B_j)\right]$ is non-decreasing in $\check{B}_i$. ■

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