Pricing of Add-On Products with Rationally Inattentive Consumers

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Abstract

We study the pricing of a multi-product seller offering main (or base) products and add-on products, e.g., cameras and lenses, when the buyer is rationally inattentive. Particularly, the buyer faces a fixed attentional capacity, i.e., an upper bound on the amount of information that the buyer can process. We characterize how the buyer allocates attention across main goods and add-on goods and show that for low levels of attentional capacity, the buyer prefers to ignore add-on products entirely. We use these results to derive seller optimal pricing. Our preliminary analysis, focusing on the case with an exogenous main good price, identifies that both the optimal add-on price as well as the seller's profits are increasing in the buyer's attentional capacity. Our work yields testable hypotheses linking buyer characteristics with choice behavior and prices and has managerial implications for pricing.

Keywords: *pricing, consumer inattention, add-on products*
Track: *Marketing Strategy & Theory*

1 Introduction

Today's market place is increasingly complex. A growing number of products become available with more—and oftentimes more sophisticated—attributes. In principle, this ensures that consumers can satisfy their needs better. At the same time, however, they may struggle more finding a suitable product if they face constraints in processing information about products. Because cognitive capacity and time are limited, complexity in one product category affects the cognitive resources available for other product categories. Naturally, such attentional externalities across product categories are relevant for multi-product retailers optimizing marketing decisions such as pricing.

For example, consider a consumer who wants to buy a camera and an additional zoom lens. Both product categories are inherently complex so that even an experienced consumer requires time and cognitive effort to make an informed choice.[1] Spending time and attention on researching cameras reduces the available resources for learning about lenses, and ultimately reduces the quality of that decision. Thus, the consumer must decide not only how to process information *within* a product category but also how to allocate scarce attention *across* product categories. How should the consumer allocate attention between cameras and lenses? How do his choices adapt when his attentional capacity changes, e.g., when more time and mental energy are available? How does the difficulty of information processing of one product category affect information processing in other categories?

These questions are especially relevant for multi-product sellers who offer both main (or base) products and add-on products. Examples of such products are plentiful: laptops and laptop bags, cars and anti-theft devices, or a hotel booking and access to (additional) meals. How should a seller optimally set her marketing mix, in particular, add-on prices? And what happens with prices when consumers' ability to learn about a category changes?

We develop an analytical model where a seller (she) offers both multiple main goods and multiple add-on goods, and the buyer (he) has a unit demand in the main good category and has a unit demand in the add-on category only if he buys a main good. *Ex ante* the buyer does not know which alternatives match his tastes best. An alternative interpretation is that he does not know which main goods fits his taste and which add-on good works best with the chosen main good. He has limited attentional capacity which determines how much information he can process about the various alternatives before making a choice. Intuitively, different factors affect this capacity, such as the buyer's cognitive ability, prior experience, and currently available amount of time. A key feature of our model is that the buyer not only decides how to learn within each category but also how to distribute his fixed attentional capacity across categories. For instance, he chooses how much time to spend comparing cameras and how much time to spend on reading about zoom lenses.

[1] As of November 20, 2022 searching https://www.amazon.com/ displays over 5.000 results for the term "digital camera" and over 2.000 results for the term "zoom lens".

We characterize how the buyer allocates attention and chooses as well as how the seller sets prices. The buyer's attentional capacity is the focal independent variable of our analysis. Our model borrows from the growing rational inattention (RI) literature that has recently found a growing interest in marketing (e.g., Jerath and Ren, 2021; Joo, 2022).

We start with a model variant where the main good price is fixed to be so low that the consumer always purchases a main good. We show that he then only buys an add-on good if his attentional capacity is sufficiently high. Moreover, both the add-on prices and the seller's profits are increasing in the (exogenous) attentional capacity. In the future, we will allow the seller to set prices in both categories, and we will study how category-specific costs of information processing, the degree of product differentiation, as well as consumer heterogeneity affect outcomes. For further details, see Section 3.

Our investigation has important managerial implications. In general, multi-product firms have to account for consumers' bounded attentional capacities, associated with observables such as age or prior product experience, when pricing products. We will provide specific guidance on how properties of a product category, e.g., its complexity, as well as consumer features determine optimal pricing which is useful for price targeting.

Our analysis yields positive implications for empirical research. On the consumer level, our analysis relates consumer characteristics that affect attentional capacity with attention allocation and choice. Moreover, our analysis predicts the likelihood of choice errors, i.e., when the buyer does not purchase the best alternative. On the firm level, we relate the consumer characteristics as well as the properties of product categories with firm pricing. For instance, our preliminary analysis implies that, all else being equal, sellers who serve consumers with a lower cognitive capacity will set lower add-on prices.

Literature. A typical explanation for the existence of add-on pricing is that of loss-leading (e.g., Ellison, 2005). The key idea is that the seller has more pricing power for add-on products and less for the main goods. In consequence, the seller charges a rather low main good price (in order to attract buyers) and obtains a rather high margin from the add-on product.

Our contribution relates to the bundling literature (e.g., Ellison, 2005). Here, a seller decides whether to offer products in a bundle for a single joint price or to sell them individually. Our work shares with this literature that we also study a multi-product seller. However, typically, in those models buyers know their product valuation while we study pricing in the presence of uncertainty and limited attention. Second, we focus on pricing in a setting where the buyer can always purchase either a main good or both a main good and an add-on good.

Second, we contribute to pricing with rationally inattentive consumers (Matějka, 2015; Jerath and Ren, 2021). To our knowledge, we are first to investigate pricing of a multi-product seller with a rationally inattentive buyer. The RI theory following Sims (2003) assumes that people allocate attention optimally while incorporating the costs associated with processing information. Conceptually, RI does not place any restriction on how decision makers can learn. Thus, under

RI decision makers choose both *how* and *how much* to learn. RI theory has been applied in a variety of economic fields, including marketing (Jerath and Ren, 2021; Joo, 2022), and finds a growing empirical support (for a survey, see Mackowiak, Matejka, and Wiederholt, 2022).

The rest of the article is organized as follows. Section 2 studies the consumer's problem and then derives the seller's optimal pricing. We conclude with Section 3 and discuss future steps of this project. All proofs are available upon request from the authors.

2 Add-on Pricing with Fixed Main Good Price

We study a game of symmetric information with a seller and a rationally inattentive buyer. There are two types of goods, main goods (M) and add-on goods (D). In each product category two varieties are available. A key assumption is that the buyer does not know *ex ante* which variety matches his taste or needs. Instead, he has to process information to determine which product fits his taste, which takes effort and time. For example, the buyer may be shopping for a camera as a main good and for a zoom lens as an add-on product. In order to determine which camera and which lens fit his needs, the buyer has to read and integrate, for instance, product descriptions and reviews, which takes time and is cognitively taxing. Attentional capacity can be thought of as capturing both the amount and quality (i.e., mental effort) of time. For example, the same amount of attentional capacity may be generated by either solving problems for one hour at high level of concentration or for two hours at low level of concentration.

The buyer has a unit demand in each of the two categories but has the option not to choose any of the offers. We assume that the consumer will only purchase an add-on good if he buys a main good. To streamline the analysis, we impose that the main good prices are so low that the buyer always prefers any of the main goods to the outside option.

We consider the following timing. First, the seller chooses the prices of the offered products. Since for now the prices of the main goods p_M are exogenously fixed, the seller chooses only the prices of the add-on products p_D. Then, the buyer decides how to learn about the products and their uncertain payoffs in the different categories. In particular, he allocates his attentional capacity across the two product categories. Learning about the products allows the buyer to update his beliefs about which products fit him. He then chooses those goods that maximize his expected payoffs given the information processed. Lastly, parties' payoffs are realized.

2.1 Buyer's problem

Choice structure. The buyer first faces a choice between two alternative main products, a_1^M and a_2^M, and an outside option a_0^M of not purchasing, denoted by the set $A_M = \{a_0^M, a_1^M, a_2^M\}$. The utility obtained from purchasing each variety depends on the seller's price p_M and on the state of the world $\omega_M \in \Omega_M$. For any state, there is exactly one good inside option yielding utility $u_M^H - p_M$. The other inside option is bad, yielding utility $u_M^L - p_M$. The outside option yields always (i.e., in all states) a payoff of zero. We streamline the analysis by imposing that $0 \leq p_M < u_M^L < u_M^H$. This ensures that the buyer will always prefer to purchase one of the main goods. In our future analysis, we will relax this assumption (see Section 3). Both options have the same *ex ante* probability of being the good option. It is convenient to define the state space in line with the action space. That is, $\Omega_M = \{a_1^M, a_2^M\}$, where ω_i^M is the state in which option i gives u_M^H and the other one gives u_M^L.

In addition to the main good, the buyer has the option to choose between two different add-on goods. The choice set is $A_D = \{a_0^D, a_1^D, a_2^D\}$, where a_0^D denotes the outside option of not purchasing. The outside good provides a payoff of zero. For each state, there is one good add-on variety yielding utility $u_D^H - p_D$ while the other gives $u_D^L - p_D$, with $u_D^L < u_D^H$. In this subsection, the price of the add-on products is fixed with $\frac{1}{2}(u_D^H + u_D^L) < p_D < u_D^H$ so that purchasing the right add-on good yields a positive payoff to the buyer while randomly purchasing an option gives a negative expected payoff. The state space for the add-on product is $\Omega_D = \{a_1^D, a_2^D\}$, where ω_i^D is the state in which option i gives u_D^H and the other one gives u_D^L. The states ω_M and ω_D are independent of each other. Without loss of generality, we impose that $u_M^H - u_M^L \geq u_D^H - u_D^L$. Denote the payoff from product a_i^k in category k with state ω_k and price p_k with $u(a_i^k, \omega_k, p_k)$.

Information processing. In modeling the processing of information, we follow the recent literature on RI. The buyer knows the underlying payoff structure but faces uncertainty about the true state which determines the optimal choices. The buyer is unrestricted in the way how he processes information. That is, he is free to choose which sources of information to process and how deep to study them. However, processing information is mentally taxing and thus associated with costs. These costs are higher when learning results in more precise posterior beliefs about the optimal products' payoffs.

Formally, let the buyer's prior belief over the realized state ω_k, with $k \in \{M, D\}$, be denoted by the prior distribution $\mu_k \in \Delta(\Omega_k)$ over the states of the world. As both states are realized with the same probability, a rational buyer will feature $\mu_k(\omega_k) = 0.5$. We model paying attention to ω_k as designing and receiving a noisy signal on the realization of ω_k to update the belief μ_k. More precise signals are more costly, and the exact cost is based on the Shannon mutual information between signals and states. We work with a capacity-based version of the RI approach (as in Naeher, 2022). That is, there is an exogenous upper bound on the amount of uncertainty that the buyer can resolve by learning.

The buyer has a fixed finite attentional capacity, $\overline{\kappa} > 0$, which can be used to reduce uncertainty about ω_M and ω_D. Let κ_k denote the amount of attention allocated to reducing uncertainty about ω_k. A key advantage of the capacity-based approach is that it links the buyer's choice for a main product to the choice for an add-on product. An alternative approach to modeling inattention is the imposition of a (fixed) unit cost of attention (Matějka and McKay, 2015). We do not follow this approach, as in such a model the buyer would consider both choice problems independently of each other.

The RI choice problem requires to determine an optimal signal structure. Matějka and McKay (2015) show that this problem can be simplified to one where the buyer chooses the *state-contingent choice probabilities* $P(a_i^k|\omega_k)$, that is, the probability of picking alternative a_i^k in state ω_k, so that it is not necessary to explicitly model signals. Costly attention can then be modeled as a constraint on uncertainty reduction. Specifically, for each category $k \in \{M,D\}$ the buyer faces the constraint

$$-\sum_{a_i^k \in A_k} P(a_i^k) \ln P(a_i^k) + \sum_{a_i^k \in A_k} P(a_i^k|\omega_k) \ln P(a_i^k|\omega_k) \leq \kappa_k, \tag{1}$$

where $P(a_i^k) = \sum_{\omega_k \in \Omega_k} \mu_k(\omega_k) P(a_i^k|\omega_k)$ is the unconditional choice probability of a_i^k. The more attention is allocated to a product category k, the larger is the expected reduction in uncertainty (measured by the left side of (1)) about the realized value of ω_k. If the buyer pays more attention to a category, he can put more weight on the correct action in the various states which increases the expected payoff in that category.

Buyer's objective. Overall, the buyer's decision problem consists of choosing the probabilities $P(a_i^k|\omega_k)$ in order to maximize the total expected payoff across the two product categories

$$\sum_{k \in \{M,D\}} \sum_{\omega_k \in \Omega_k} \mu_k(\omega_k) \left(\sum_{a_i^k \in A_k} P(a_i^k|\omega_k) u(a_i^k, \omega_k, p_k) \right), \tag{2}$$

subject to the constraint on uncertainty reduction (1) and the attention budget constraint

$$\kappa_M + \kappa_D \leq \overline{\kappa}. \tag{3}$$

The buyer faces a trade-off. Allocating attention to one category results in more frequently choosing the optimal alternative in that category. At the same time, it reduces the available attention for the other category since total attentional capacity is fixed. The buyer will typically distribute attention such that the marginal benefits of attending to the main good category equal those in the add-on category.

2.2 Buyer's problem: Analysis

Solving the buyer's problem follows mostly the steps in Matějka and McKay (2015) and Naeher (2022), and yields choice probabilities for all alternatives. This solution is then used in the seller's problem to derive optimal pricing. We obtain the necessary conditions for a solution by characterizing the state-conditional choice probabilities as stated in the following Lemma.

Lemma 1 *For all alternatives a_i^k in product category k that are chosen with a strictly positive unconditional probability, $P(a_i^k) > 0$, the conditional choice probability in state ω_k reads*

$$P(a_i^k|\omega_k) = \frac{P(a_i^k)e^{u(a_i^k,\omega_k,p_k)/\lambda}}{\sum_{b\in A_k} P(b)e^{u(b,\omega_k,p_k)/\lambda}}, \tag{4}$$

where λ is the buyer's shadow price of attention.

The shadow price of attention λ expresses the marginal change of the buyer's optimized payoff when the attentional capacity $\overline{\kappa}$ increases. In order to fully characterize the solution to the buyer's problem, we need to determine the unconditional choice probabilities $P(a_i^k) > 0$. In the present model, there are only two cases for the optimal unconditional choice probabilities, which simplifies the subsequent analysis.

Lemma 2 *When the price of the main good is sufficiently low (i.e., $p_M \leq u_M^L$), then the optimal unconditional choice probabilities are $P^*(a_1^M) = P^*(a_2^M) = \frac{1}{2}$ for the main goods and*

$$\left(P^*(a_0^D), P^*(a_1^D), P^*(a_2^D)\right) \in \left\{\left(0, \frac{1}{2}, \frac{1}{2}\right), (1,0,0)\right\}, \tag{5}$$

for the add-on goods.

By assumption, each main good provides a higher payoff than the outside good and so the buyer never purchases the outside good. With the add-ons there are two cases: He will either always or never choose an add-on good. In particular, he will never mix between the add-on goods and the outside option. Intuitively, there is always an add-on good that leads to a higher utility than the outside option, and the buyer knows in advance how much attention is needed to make a purchase profitable in expectation. It is thus never optimal to pay attention to the offered add-on products and then not to purchase.

We can use the above results in order to express the probability for a choice error, that is, the probability to choose an alternative in a category when it only provides a low gross payoff u_k^L:

$$\delta_k^L(\lambda) = \frac{1}{2}\left(P(a_1^k|\omega_2^k) + P(a_2^k|\omega_1^k)\right)\bigg|_\lambda = \frac{e^{u_k^L/\lambda}}{e^{u_k^H/\lambda} + e^{u_k^L/\lambda}}, \tag{6}$$

where λ is the Lagrange multiplier. Similarly, define the probability of a correct choice as $\delta_k^H(\lambda) = 1 - \delta_k^L(\lambda)$. This allows to derive empirical hypotheses in the future analysis.

Optimal attention allocation across categories. Recall that the buyer decides first to either purchase one of the add-on goods or not. Before specifying when each case arises it is helpful to use the unconditional choice probabilities to derive expressions for the optimal allocation of attention and associated expected payoffs in each of the two cases.

Lemma 3 *If the buyer purchases an add-on product, then the optimal allocation of attention across the two product categories $k \in \{M,D\}$ is given by*

$$\kappa_k^*(\lambda) = \ln(2) + \delta_k^H(\lambda)\ln\left(\delta_k^H(\lambda)\right) + \delta_k^L(\lambda)\ln\left(\delta_k^L(\lambda)\right), \tag{7}$$

where $\lambda > 0$ is the shadow price of attention. The expected payoff for each category k reads

$$E[u_k(\kappa_k^*)] = u_k^H \delta_k^H(\lambda) + u_k^L \delta_k^L(\lambda) - p_k. \tag{8}$$

If the buyer does not buy an add-on product, then $\kappa_D^* = 0$, $\kappa_M^* = \overline{\kappa}$, and the expected payoff for the main good has the same functional form as in (8), but with a different value of λ.

Note that the optimal values of κ_M and κ_D are independent of prices p_M and p_D according to equation (7). Prices only determine whether information is processed but not how. This is intuitive, since once the buyer chooses to purchase from either of the categories, the corresponding price is the same within each category. Note, however, that the add-on price p_D determines whether the buyer purchases from the add-on category or not. With Lemma 3 we show next that the buyer's optimal behavior is characterized by two cutoff values of the attentional capacity $\overline{\kappa}$.

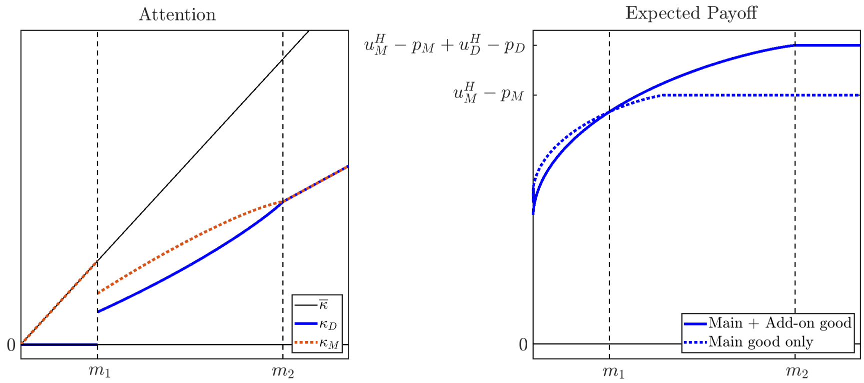
Proposition 1 *The buyer's optimal behavior is characterized as follows. For given prices and parameters, there are two cut-offs m_1 and m_2. When the attentional capacity $\overline{\kappa}$ is small, $\overline{\kappa} < m_1$, the buyer pays attention only to the main good. When the capacity is intermediate, $m_1 \leq \overline{\kappa} \leq m_2$, the buyer resolves some uncertainty about the main good and the add-on good category. When $\overline{\kappa} \geq m_2$, the buyer fully resolves uncertainty in both product categories. The buyer purchases only one of the main goods when $\overline{\kappa} < m_1$ and both one of the main goods and one of the add-on goods otherwise.*

Note that the buyer's optimal strategy described in Proposition 1 features a discontinuity in the amount of attention allocated to each of the two product categories. Figure 1 provides a graphical illustration. Starting with a value $\overline{\kappa} > m_1$, as $\overline{\kappa}$ decreases below the cutoff m_1, κ_D^* jumps from a strictly positive value to zero (and κ_M^* is increased by the same magnitude as attention is shifted from A_D to A_M). Intuitively, this discontinuity exists because it is never optimal to purchase an add-on good under very small amounts of attention κ_D, as the risk of selecting a bad variant is then too high.

2.3 Seller's Problem

The seller sets the price level $p_D \geq 0$ for the add-on product category. Since products within each domain are *ex ante* homogeneous it is optimal to set symmetric prices. The price of the

Figure 1: Buyer's optimal allocation of attention and expected payoff as functions of $\overline{\kappa}$



Note: Simulation for parameter values: $u_M^H - p_M = 5$, $u_M^L - p_M = 1$, $u_D^H - p_D = 1$, $u_L^H - p_D = -2$.

main good is exogenously fixed as the seller has no pricing power in this category. The seller's expected payoff is therefore given by

$$\Pi = (p_M - c_M)(P(a_1^M) + P(a_2^M)) + (p_D - c_D)(P(a_1^D) + P(a_2^D)) \tag{9}$$

where p_M and p_D are the respective prices and c_M and c_D are costs for each product category. We assume that $p_M > c_M$ and $c_D < u_D^L$ so that the seller always offers the add-on products.

2.4 Seller's Problem: Analysis

Recall that the price of the main good is exogenous and such that the buyer always buys a main good. From Lemma 2, we have that the buyer purchases one of the add-on goods with a probability of zero or one. We break the tie by assuming that when the consumer is indifferent between learning about the add-on products or choosing the respective outside option, he prefers the former. Since the seller's profits are increasing in the price of the add-on good, the seller will price such that the consumer is indifferent between learning about and choosing only a main good or learning and choosing about goods from both categories. With higher capacity the buyer can process more information which increases his expected payoff when purchasing from both product categories. Anticipating the buyer's increasing willingness to pay, the seller raises p_D.

Proposition 2 *The seller's optimal price p_D^* is determined by the condition*

$$p_D^* = E[u_M(\kappa_M^*(\lambda_2))] + E[u_D(\kappa_D^*(\lambda_2))] - E[u_M(\kappa_M^*(\lambda_1))],$$

where λ_1 is the shadow price of attention if only the main good is purchased and λ_2 is the shadow prices if a purchase from both categories is made. At this price the consumer will learn about both product categories and purchase one product from each category. Both the price p_D^* and the seller's profits increase in the attentional capacity $\overline{\kappa}$.

3 Conclusion

We study a model of add-on pricing with a rationally inattentive buyer who faces an attentional capacity constraint. Our preliminary analysis highlights that consumers' cognitive capacities should be accounted for when pricing (add-on) products due to the attentional externality that we identify. Information processing difficulties in one product category impact information processing and thus choices in other categories.

In the next intended step of our analysis, the seller prices both the main and the add-on goods. We consider this to be an important step towards a realistic analysis since typically retailers do have pricing power over most of their goods. Further, we cover the following extensions. First, we will study the impact of category-specific information processing costs. In practice, main goods likely are more complicated than add-on goods and we conjecture that this will reduce the extractable surplus. Second, we will investigate the effect of horizontal differentiation on pricing. A higher degree of horizontal product differentiation will increase the costs of making an erroneous choice which in turn affects the buyer's optimal allocation of attention. Finally, a retailer in practice is likely to face consumers who are heterogeneous with respect to the attentional capacities, e.g., $\overline{\kappa}_H > \overline{\kappa}_L$, which provides opportunities for price discrimination.

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