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The optimal sequential information acquisition structure: A rational utility-maximizing perspective

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ABSTRACT

We consider a rational utility maximizer decision maker (DM) who must gather two pieces of information from a set of multidimensional products before making a choice. We analyze the resulting sequential information acquisition process where the DM tries to find the best possible product subject to his information acquisition constraint. In addition, we introduce publicly observable signals that allow the DM to update his expected utility functions following a standard Bayesian learning rule. Even though it seems intuitively plausible to assume that the transmission of positive and credible information may lead DMs to accept any product signaled more eagerly, this paper illustrates how transmitting credible positive information is not sufficient to decrease the rejection probability faced by the information sender on its set of products. A significant difference in product rejection probabilities arises depending on the characteristic on which signals are issued, as will be illustrated numerically for both risk-neutral and risk-averse DMs.

1. Introduction and literature review

The current paper formalizes and studies the optimal information acquisition behavior of a rational decision maker (DM) when choosing among multidimensional products defined by vectors of characteristics. We analyze the case where the decision process is based on the possibility of collecting two pieces of information. The proposed model accounts for the assimilation of publicly observable *credible* signals through a standard Bayesian learning setting. The introduction of signals within a multi-dimensional information acquisition framework allows us to account explicitly for the effects that different risk attitudes, number and type of signals have on the optimal information acquisition behavior of DMs. Signals will be introduced both on the first and the second characteristic spaces defining a product in order to intuitively differentiate the role played by observations from that played by expectations in the formation of DMs' acceptance/rejection probabilities.

Economists have tried to explain why the introduction of newly developed technologies takes such a long time to be diffused [assimilated] among the population, see [1,2] for a review of the literature. This is the case, since it seems intuitively

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plausible to assume that once a DM recognizes a new product as an improvement over a previous version, he should immediately purchase it [if we abstract from considerations regarding excessive prices and other market frictions]. This is also the main idea behind the operational research literature, where the dynamic programming models employed to analyze the introduction of technological innovations rely on the *ad hoc* assumption that DMs recognizing these improvements will immediately purchase the corresponding product, see [3,4]. It should be highlighted that Smith and Ulu [3] constitutes a partial exception to this point, as they also obtain delays in the adoption of technologically superior products when repeated purchases are allowed among DMs. This research line remains however focused on the importance that search costs have in limiting the information processing capacity of, generally risk-neutral, DMs when deciding whether to continue or stop their search within settings defined by the adoption of a given technology, see, for example, [5].

The literature analyzing the speed of product updates concentrates traditionally on the cost effects for the firm, such as product cannibalization and product development costs, and the resulting firm's incentives regarding optimal new-product introduction timing and product-quality decisions, see [6,7] for a duopolistic case, and [8]. It is generally the supply side of the system the one considered when studying whether a technologically superior product should be introduced in the market. If the introduction of a new and improved version of a product is delayed, it is the supplier the one that may decide to do so due to the already mentioned time inconsistency problem that causes its old and new products to cannibalize each other, see [9] for a monopolistic case. This is assumed to be the case even if the underlying technologies required for the development of the new product are already available.

As Mallik and Chhajed [10] state, once a premium product is introduced, the valuations of the consumers change. Similarly to the previous papers, these authors discuss the conditions under which a firm should expand its product line and study the effects of cost savings and customer valuation changes. Once again, this type of approach imposes a firm's perspective on the product acquisition process, as seems to also be the case when considering dynamic advertising models under a wide range of market competition structures, see [11] for a literature review. That is, these models assume that as soon as DMs recognize the technological superiority of the new products being introduced they will readily purchase them or at least do so with a higher probability. As a result, it is generally assumed that delaying the introduction of a new [technologically superior] product translates into a failure to capitalize on customer willingness-to-pay for the improved technology. Moreover, there is empirical evidence illustrating how delays have a statistically significant negative effect on profitability [via returns on the assets] of the corresponding firms, see [12].

Information scientists have started to take an interest in the strategic consequences that the process of information transmission has for the information acquisition of and subsequent choices made by DMs. However, the corresponding literature seems to concentrate on the long run stability properties of the population distributions that follow from the survival rates defined in different agent-based models, see [13]. In this regard, the immediate effects that follows from the limited capacity of DMs to assimilate information when considering multiple characteristics are rarely analyzed. That is, DMs are assumed to purchase information continuously and assimilate it rationally. Consequently, we tend to believe that any product improvement constitutes an increase in the purchase probability if it is credible and rationally assimilated by DMs. The current paper illustrates how, even in the simplest, thought non-trivial, scenario, this is not necessarily the case and how the characteristic on which positive and credible information is issued constitutes an important determinant of the acceptance/rejection probability defined by DMs.

We will bias our notation towards the economic side of the literature and express the information acquisition process of DMs in utility terms. This notational choice is made to differentiate our model from the value functional forms required by the dynamic programming and operations research literatures. Due to formal reasons that will become evident below, the current model cannot be defined in the standard dynamic programming terms commonly considered within these branches of the literature. That is, the information acquisition process described through the paper should be redefined after each observation is gathered by the DM and recalculated in terms of *all previously observed variables, their sets of possible combinations and corresponding expected payoffs*. In this sense, adding dimensions in the form of additional observations [based on the general environment introduced in the next section] and calculating the resulting strategic possibilities should constitute immediate extensions of the current paper.

Intuitively, the small dimensionality of the model could be justified to some extent in terms of the satisficing capacity constraints defined by Simon [14] within a fully rational environment. Similarly, the value of information could be used to impose a limit on the number of observations acquired, see [15], and strategic considerations in terms of information costs could be addressed in future extensions of the paper. Moreover, the literature usually concentrates on a small number of attributes when describing the products available to DMs, i.e., quality and preference in the consumer choice environment of [16], performance and cheapness in the economic setting of [17], and variety and quality in the operational research one of [18].

We provide some additional intuition regarding the constraints imposed on the number of observations acquired in the following subsection.

1.1. Motivation

We illustrate how the willingness of DMs to purchase a newly introduced product depends on their degree of risk aversion and the unobserved characteristic on which signals are issued. In doing so, we reach the same type of conclusion as [19,20,4] regarding the effect that first order stochastic dominance improvements on expected revenue/utility have on the incentives of DMs to adopt a new technology. That is, signaling the development of a more advanced technology does