



Interfaces with Other Disciplines

Expert-mediated sequential search ☆

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ABSTRACT

This paper studies markets, such as Internet marketplaces for used cars or mortgages, in which consumers engage in sequential search. In particular, we consider the impact of information-brokers (*experts*) who can, for a fee, provide better information on true values of opportunities. We characterize the optimal search strategy given a price and the terms of service set by the expert, and show how to use this characterization to solve the monopolist expert's service pricing problem. Our analysis enables the investigation of three common pricing schemes (pay-per-use, unlimited subscription, and package pricing) that can be used by the expert. We demonstrate that in settings characteristic of electronic marketplaces, namely those with lower search costs for consumers and lower costs of production of expert services, unlimited subscription schemes are favored. Finally, we show that the platform that connects consumer and experts can improve social welfare by subsidizing the purchase of expert services. The optimal level of subsidy forces the buyer to exactly fully internalize the marginal cost of provision of expert services. In electronic markets, this cost is minimal, so it may be worthwhile for the platform to make the expert freely available to consumers.

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1. Introduction

We study markets in which consumers search sequentially for a single item that they are interested in acquiring. A classic example is a consumer looking to buy a used car. She will typically investigate cars one at a time until she decides on one she wants. Similar models apply in a range of settings beyond consumers purchasing goods: for example, sequential search theory has been applied to job-search, house search, technology R&D, and mate search (Bental & Peled, 2002; Janetos, 1980; Lippman & McCall, 1976; Mortensen & Pissarides, 1999; Terwiesch & Loch, 2004; Wiegmann, Weiner-smith, & Seubert, 2010). Analysis of search is becoming increasingly important in the context of modern electronic marketplaces because of the emergence of a plethora of online sellers and the ability to access them easily (Bakos, 1997; Brynjolfsson & Smith, 2000; Haynes & Thompson, 2008).

The main tradeoff in sequential search arises from the fact that there is a cost incurred in finding out the true value of any

opportunity encountered (Atakan, 2006; Kephart, Hanson, & Greenwald, 2000; Lippman & McCall, 1976). For example, there is a cost to arranging a meeting to test drive a car you are considering purchasing, or to evaluating an offer received when shopping for a mortgage online. The searcher needs to trade off the potential benefit of continuing to search and seeing a possibly more valuable opportunity with the costs incurred in doing so (Grosfeld-Nir, Sarne, & Spiegelier, 2009). An additional complexity is that searchers often only obtain a noisy signal of the true value. For example, the drivetrain of a used car may not be in good condition, even if the body of the car looks terrific. Similarly, when shopping for a loan online, a promising offer with a low interest rate might turn out to be a poor offer due to stringent terms and conditions, or excessive initiation fees and closing costs. The relaxation of the assumption of perfect values not only changes the optimal strategy for a searcher, it also leads to a niche in the marketplace for new information brokers. These information brokers, or *experts*, are service providers whose main role is to inform consumers or searchers about the values of opportunities. An expert offers the searcher the option to obtain a more precise estimate of the value of an opportunity in question, in exchange for the payment of a fee (which covers the cost of providing the service as well as the profit of the expert). In the used-car example, independent mechanics or agencies like Carfax that provide reports on car histories can serve as experts. The expert does not necessarily need to be an entity external to the platform the users use for reviewing opportunities. Instead, it can be a service offered by the platform itself.

☆ A preliminary version of some of these results appeared in the Proceedings of the Tenth International Conference on Autonomous Agents and Multiagent Systems (Chhabra, Das, & Sarne, 2011).

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¹ Parts of this work were done when Chhabra and Das were at Rensselaer Polytechnic Institute and at Virginia Tech.

Prior work on the problem of sequential search with noisy signals has treated the expert (or equivalent) as exogenous to the model, assuming that the searcher can purchase information on the true value of an opportunity as needed (MacQueen, 1964; Wiegmann et al., 2010). In this work we investigate what happens when the expert and the platform connecting experts and searchers are both potentially strategic players with their own incentives.

1.1. This paper

We introduce a model of a search market with a self-interested expert that attempts to maximize her expected profit. She must decide how to set prices and other characteristics of the services she offers, choosing from a rich set of (possibly non-linear) pricing models. The expert is taken to be a monopolist, since in many situations of interest the economies of scale involved in production of expert services favor the emergence of monopolies, and even when there are competitors in a market, the platform that connects consumers and experts may have a special relationship with one provider, or may provide expert services itself as a value-added product.

In order to study the monopolist's pricing problem, we first need to characterize the optimal response of a searcher to the expert's strategy. The most common pricing models used in today's markets are a la carte (pay-per-use) pricing, fixed-fee pricing (subscriptions to services) and non-linear package pricing (where the expert sells packages of a fixed number of uses of her services for a given price) (the first two pricing models are actually special cases of the third, but worthy of special consideration because of their ubiquity). For the general case of non-linear pricing we prove that, under a standard stochastic dominance assumption on the signal structure (that higher signals are "good news" (Milgrom, 1981)), the optimal search rule is characterized by a "double reservation value" strategy, whenever the expert can be used only upon purchasing a new package, and a "single reservation value" strategy whenever a purchased package has not been completely exhausted. With the double reservation value strategy, the searcher rejects all signals below a certain threshold, resuming search, and accepts all signals above another threshold, thus terminating search without querying the expert; the agent purchases a new service package and queries the expert for all signals that are in between the two thresholds. With the single reservation value the searcher rejects all signals below a certain threshold, resuming search, and queries the expert otherwise. This strategy has some similarities in structure to the optimal strategy in other partial information search models, but previous models do not analyze the general case of a service package.

We use the derivation of the optimal search strategy to find the monopolist expert's pricing strategy and then show how the expert's optimal strategy is affected by the fundamental features of the underlying environment, such as consumer search costs and the marginal cost of production of additional units of expert services. We find that fixed-fee or subscription models are likely to be preferred by the expert in settings with low search costs and low marginal costs of producing extra reports, which are both key features of online markets.

Finally, we use the combined characterization of optimal strategies for the searcher and the expert to study the problem from the perspective of the platform that brings them together. We find that the platform can increase social welfare by subsidizing access to expert services, and that social welfare is maximized when consumers pay exactly the marginal cost of production of expert services.

1.2. Contributions

To summarize, this paper makes four main contributions to the literature. (1) We characterize the structure of optimal search strategies when experts offer packages of (non-linearly priced) services, extending existing literature on a la carte service pricing. (2) We formulate and solve the monopolist expert's pricing problem, treating the expert as the first mover to whom searchers respond optimally. These two methodological contributions allow us to (3) formulate a novel model of noisy search where the cost of improved information acquisition is endogenous to the model, and derive results on prices as well as expert and searcher welfare in the model. Finally, (4) we derive implications for the platform that connects searchers and experts, and prove novel results about optimal subsidization in search markets. A key focus throughout our work is on understanding how important features of electronic markets, namely low search costs and low costs of delivery of expert services, affect outcomes in these expert-mediated search markets.

2. Related work

This paper touches on several different literatures. The technical aspects of the problem from the searcher's perspective are grounded in the theory of sequential search (Hak Chun, 1996; Lippman & McCall, 1976; McCall, 1970). The optimal stopping rule in sequential search has been widely studied, and is often a *reservation strategy*, where the searcher should terminate search once she encounters an opportunity which has a value above a certain reservation value or threshold (McMillan & Rothschild, 1994; Weitzman, 1979). In some specific instances, the optimal strategy is a double reservation value one (Kang, 2005; MacQueen, 1964).

Noisy signals have been introduced into optimal stopping problems and search models previously (Wilson, Szechtman, & Atkinson, 2011). In particular, MacQueen (1964) characterizes optimal search when disambiguating the uncertainty associated with a given opportunity incurs a fixed cost (the equivalent to the a la carte (pay-per-use) pricing method). However, MacQueen does not analyze more general information pricing schemes as we do in this paper. More importantly, MacQueen's work focuses solely on the searcher's problem, assuming fixed costs of information acquisition, and does not consider the strategic and systemic aspects of the problem from the perspective of the expert or the platform. Our model assumes that the disambiguation of noisy signals is performed by a strategic agent (the expert) who serves as an information broker and sets the cost to the decision-maker (searcher) of acquiring more information. We investigate the implications of this, focusing particularly on what it can tell us about strategies for the expert and for the platform that connects searchers with opportunities, and thus also with experts.

Other work on optimal stopping problems in the presence of noisy signals (e.g., the work of Monahan (1980, 1982)), is also typically limited to a la carte pricing, and significantly different from ours both in model formulation and technical detail. This also includes work on how much costly information it makes sense to acquire before making a decision (Moscarini & Smith, 2003) and on multi-attribute sequential search where additional attributes can be revealed at certain costs along the search path (Lim, Bearden, & Smith, 2006; Wiegmann et al., 2010). In addition to the technical differences between these models and ours, as in the case of MacQueen, all these models also consider the cost of obtaining the information to be set exogenously (i.e., in a non-strategic manner) thus precluding any insights from the points of view of the expert and the platform.

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