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Dynamic mechanism design: Dynamic arrivals and changing values ☆

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ABSTRACT

We study the optimal mechanism in a dynamic sales relationship where the buyer's arrival date is uncertain, and where his value changes stochastically over time. The buyer's arrival date is the first date at which contracting is feasible and is his private information. To induce immediate participation, the buyer is granted positive expected rents even if his value at arrival is the lowest possible. The buyer is punished for arriving late; i.e., he expects to earn less of the surplus. Optimal allocations for a late arriver are also further distorted below first-best levels. Conditions are provided under which allocations converge to the efficient ones long enough after contracting, and this convergence occurs irrespective of the time the contract is initially agreed (put differently, the so-called "principle of vanishing distortions" introduced by Battaglini (2005) continues to apply irrespective of the buyer's arrival date).

1. Introduction

Markets for most goods are highly dynamic. Buyers may become interested in acquiring goods at different times, such as when they first encounter advertisements for the product. Once in the market, their preferences can be expected to change. Buyers' eagerness to consume often hinges on their own circumstances. Purchasers of cellular telephone plans or wireless internet packages, for instance, have preferences that fluctuate with their available leisure time and contact with friends. Commercial buyers' needs may change in long-term supply relationships. For instance, a restaurant's preferences for acquiring high-quality ingredients from a supplier may vary with changes in its menu, which may come at the whim of the chef.

This paper studies the optimal mechanism for a buyer who has vertical preferences over the quality levels that the seller can supply. The buyer's arrival date to the market (which is the first date he can contract with the seller) is uncertain and, having arrived, his preferences evolve stochastically with time. The key difficulty for designing the profit-maximizing mechanism in such a setting is that the buyer is strategic, and can "hide" his (privately known) arrival to the market. That is, he may participate in the mechanism only at the moment of his choice. In particular, the buyer may prefer to wait to learn if his preferences will change before participating.

☆ This paper adapts the second part of my earlier work "Durable Goods Sales with Dynamic Arrivals and Changing Values" to a simpler setting where the good is not durable. The paper has benefited from detailed comments from Simon Board, Rahul Deb, Jeff Ely, Igal Hendel, Konrad Mierendorff, Alessandro Pavan, Bill Rogerson, Bruno Strulovici and Rakesh Vohra. This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 714147).

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That the revelation principle applies in our set-up means that there is never any loss in inducing the buyer to participate in the mechanism immediately upon arrival; in fact, such a policy is typically strictly the most profitable. Because a buyer who has not yet participated in the mechanism retains the ability to wait and participate at a later date, he enjoys a positive outside option. This outside option is *endogenous*, since it depends on the seller's choice of mechanism for later participation dates. An optimal mechanism therefore punishes late participation: If the buyer participates later, then he faces worse terms of trade, purchases quality levels which are distorted further below their efficient levels, and expects to earn less rent. By lowering the option value of waiting, the seller extracts more of the surplus for herself. Our finding thus contrasts with the much simpler case of constant values, where the optimal mechanism involves a repetition of the static optimum, and where the buyer therefore receives the same treatment irrespective of the participation date. Because values are persistent in our setting, how the buyer fares if delaying participation depends on his current value for quality, and this means the value of his outside option is type dependent.[1]

The quality levels supplied under a contract signed at a given date τ depend critically on the ratio between the probability of arrival at date τ and the probability of arrival at any earlier date. A smaller ratio implies that the seller cares relatively less about efficiency at date τ and more about limiting the rents available in case of arrival before τ. When the ratio decreases with time, the optimal quality allocations thus become increasingly (downward) distorted at later contracting dates. When the horizon is infinite, and when the buyer arrives at each date with positive probability, the ratio necessarily converges to zero with time. The rents the buyer expects for an optimal mechanism then converge to zero as the participation date goes to infinity.

Although the buyer receives lower qualities if he arrives late, it is often still the case that quality prescriptions converge to their first-best levels after a sufficiently long relationship. Put differently, the "principle of vanishing distortions" first described by Battaglini (2005) and adapted to richer settings by Pavan, Segal and Toikka (2014) continues to hold. The reason is that quality choices at dates long after the relationship has commenced have little effect on the information rents that the buyer expects, as perceived at the time of contracting. This is familiar from the existing literature: loosely, the result is driven by an assumption that a buyer's initial value for quality is a poor predictor of his value far in the future. Of course, many stochastic processes fail such a restriction; existing work (see, e.g., Boleslavsky and Said, 2013; Pavan et al., 2014; Skrzypacz and Toikka, 2015; and Bergemann and Strack, 2015) shows how distortions can fail to vanish if the type process is sufficiently persistent.

Outline. The rest of the paper is as follows. The remainder of this section provides a review of related literature. Section 2 then introduces a model in which the buyer can have at most two values for quality (building on work by Battaglini, 2005, as explained below). Section 3 provides a detailed analysis of the two-value model and Section 4 concludes. Appendix A provides proofs of all results relating to the two-value model, while Appendix B provides additional results (with proofs) for the model with a continuum of values (which builds, especially, on work by Pavan et al., 2014).

1.1. Related literature

This paper connects two distinct lines of research in dynamic mechanism design. One strand considers profit-maximizing mechanisms for agents whose preferences evolve stochastically with time and who are available to participate at the date the principal fixes the mechanism (see, e.g., Baron and Besanko, 1984; Besanko, 1985; Courty and Li, 2000; Battaglini, 2005; Eso and Szentes, 2007; and Pavan et al., 2014). The other considers dynamic mechanisms when agents arrive over time but preferences do not change (see, e.g., Conlisk et al., 1984; Board, 2008; Gershkov and Moldovanu, 2009; Said, 2012; Pai and Vohra, 2013; and Board and Skrzypacz, 2016).[2] While these strands have mainly developed independently (see Bergemann and Said, 2011, for a summary), combining features from both is an important step towards realism and allows us to uncover new tradeoffs.

The analysis in the main text focuses on a highly tractable framework that builds on Battaglini (2005). Battaglini studies a dynamic contracting setting with a fixed and commonly known participation date, and where the buyer can have only two values for quality. The buyer's value evolves according to a first-order Markov process. The key novelty in our set-up is that the buyer's arrival date to the market – which is the first date at which a contract can be agreed – is instead uncertain and the buyer's private information. The optimal mechanism must therefore permit participation at each possible arrival date (unlike in Battaglini's model, where the buyer is simply excluded forever if he does not participate at the first opportunity). An important difficulty, new relative to Battaglini's paper, is that design of the mechanism is non-separable across different participation dates. For example, adjustments to how the buyer is treated when participating at any given date typically necessitate adjustments also to the treatment for earlier dates, in order to preserve the buyer's incentive constraints (in particular, to guarantee timely participation in the mechanism).

[1] See Jullien (2000) for a study of (static) mechanism design with type-dependent outside options.

[2] There is also a literature with dynamic arrivals but without commitment; examples include Conlisk, Gerstner and Sobel (1984) and Dilme and Li (2016).