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Note

# Coordinating adoption decisions under externalities and incomplete information

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ABSTRACT

A monopolist sells a good whose value depends on the number of buyers who adopt it as well as on their private types. The seller coordinates the buyers' adoption decisions based on their reported types, and charges them the price based on the number of adoptions. We study ex post implementable sales schemes that are collusion-proof, and show that under the revenue maximizing scheme, more buyer types are willing to adopt when there are more adoptions, and the number of adoptions is maximized subject to the participation constraints.



## 1. Introduction

Goods have adoption externalities when their value to any consumer depends on the consumption decision of other consumers. A classical example of a good with adoption externalities is a telecommunication device whose value depends directly on the number of other people using the device. Other leading examples include the operating system (OS) of PC's, fuel-cell vehicles, social networking services, industrial parks, and so on. The nature of externalities may be purely physical as in the case of the telecommunication device, but may also be market based or psychological. Market-based externalities arise when more users of a good induces the market to provide complementary goods that enhance the value of the good. More users of a fuel-cell vehicle, for example, encourages entry into the market of charge stations, which leads to the increased value of such vehicles. On the other hand, much of bandwagon consumption in the fashion, toy and electronic industries is best explained by psychological externalities where consumers' tastes for a particular good are directly influenced by the size of its consumption. When all types of externalities are considered, it would be no exaggeration to say that a substantial fraction of goods have such a property.

Despite their importance, goods with adoption externalities have received relatively little attention in economic theory.[1] Analysis in the literature has mostly focused on the resolution of the coordination problem arising from the multiplicity of equilibria. When every consumer expects others to adopt the good, its expected value is high enough to render adoption a rational decision (at least for some price). On the other hand, when every consumer expects no other consumers to adopt, then its low expected value makes no adoption rational. Expectation is self-fulfilling in both cases, leading to multiple,

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[1] Rohlfs (1974) is the first to give a theoretical analysis of goods with externalities.

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Pareto-ranked equilibria. A subsidy scheme as proposed by Dybvig and Spatt (1983) is one way to eliminate the problem by promising to compensate the adopters when the number of adoptions is below some threshold. The existence of Pareto-ranked equilibria is also the main focus of the analysis of intertemporal adoption decisions.[2] In contrast, the problem of revenue maximization by a monopolist has been analyzed only indirectly either under the implicit assumption that higher participation implies higher revenue, or through the analysis of introductory prices, a common practice of setting a low price for early adopters and a higher, regular price for others (Cabral et al., 1999).[3] The objective of this paper is to directly explore the revenue maximizing coordination and pricing of a good with adoption externalities under incomplete information.

We suppose that there are $N$ ex ante symmetric buyers who choose whether to adopt the seller's good or not. A (*user*) *group* is the set of adopting buyers. Each buyer $i$'s valuation $v_i$ of the good is an increasing function of the size of the user group and his private type which is distributed over the unit interval. A *coordinating scheme* determines a user group as a function of the buyers' reported types, and determines transfer from each buyer as a function of the size of the realized user group.

We envisage the situation where the buyers know each other well and collusion among them is a plausible concern for the seller as in the case of the sale of an intermediate good where the buyers come from the same industry. Specifically, coordinating schemes are required to be not only strategy-proof, but also coalitionally strategy-proof. Coalitional strategy-proofness is a strengthening of strategy-proofness, and ensures that at any type profile, no subset of buyers can benefit from jointly misreporting their types.

Our analysis highlights one simple property of a coordinating scheme named monotonicity. Given the price of each group, consider the marginal type of a buyer who is just indifferent between adopting as part of the size $n$ user group for price $t^n$ and not adopting. We say that a size $m$ user group priced at $t^m$ is *more accessible* than a size $n$ user group priced at $t^n$ if, whenever the marginal type for the size $m$ group is lower than the marginal type for the size $n$ group.[4] In other words, one group is more accessible than another if any buyer type who accepts to be part of the first group accepts to be part of the second group. We say that a coordinating scheme is *monotone* if (1) a larger user group is always more accessible than a smaller user group, and (2) the largest user group is chosen as permitted by individual rationality. The latter property implies that a monotone scheme is efficient in the sense that it does not exclude any buyer type who is willing to adopt given the price and the decisions of other buyers.[5] We show that a monotone coordinating scheme is coalitionally implementable, and establish as the main theorem of this paper that a coordinating scheme is monotone if it is optimal in the class of coalitionally implementable schemes.

The idea of a coordinating scheme generalizes an inducement scheme proposed by Park (2004). An inducement scheme, which itself generalizes the subsidy schemes discussed above to the incomplete information environment, is a sales mechanism in which the transfer between the seller and buyers depends on the realized user group. It first posts a price of each user group, and then lets the buyers simultaneously decide whether to adopt or not. Because of this feature, the buyers' adoption decisions are independent of one another under an inducement scheme. In contrast, we model a seller who actively coordinates adoption decisions, and propose a sales scheme that works as a coordinating device.

The perceived multiplicity of equilibria in problems with adoption externalities makes (coalitional) strategy-proofness a preferable incentive condition compared with Bayesian incentive compatibility. One unique aspect of the present analysis is that it combines (coalitional) strategy-proofness, which is independent of the type distribution, and revenue maximization, which requires the specification of the distribution.[6] The optimality of a monotone scheme holds for any type distribution, and hence is *distribution-free*.

In line with the existing research on adoption externalities, we suppose that pricing is *adoption contingent* in the sense that a single price is associated with each possible group. Adoption-contingent pricing under externalities is extensively analyzed in various contracting problems where the principal maximizes the revenue or minimizes the cost.[7] Introduction of incomplete information about buyer types distinguishes our model from the existing models of adoption-contingent pricing.

As a result of revenue maximization, only a subset of buyers may end up consuming the good. A similar framework is found in the problem of excludable public goods where the planner can exclude some agents from consumption. However, the public good literature typically assumes that the good's value depends on the amount of contributions from the agents rather than their adoption status, and focuses on the efficient cost sharing rather than revenue maximization.[8]

[2] See Gale (1995, 2001), Ochs and Park (2010), and Shichijo and Nakayama (2009).

[3] Sekiguchi (2009) examines the monopolist's revenue in the dynamic setup as in Gale (1995) when the price is held constant over time and across consumers. Aoyagi (2010) analyzes a related but different problem in which a monopolist attempts to maximize revenue when the buyers' valuations mutually depend on one another's types.

[4] Note that this does not imply that $t^m < t^n$ since the values of the two groups are different.

[5] In fact, it will be shown that a symmetric coordinating scheme is efficient in this sense and satisfies individual rationality only if it is monotone.

[6] A similar approach is taken by Shao and Zhou (2008), who combine strategy-proofness and expected surplus maximization in an allocation problem of an indivisible good to two buyers. One interpretation is that the buyers have common knowledge about one another's type, but the seller only knows their distribution.

[7] See Armstrong (2006), Bernstein and Winter (2010), and Segal (2003), among others.

[8] See, for example, Moulin (1994), Deb and Razzolini (1999a, 1999b), and Bag and Winter (1999).