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Author:

e-mail:

[MktgSci@notes.cba.ufl.edu](mailto:MktgSci@notes.cba.ufl.edu)

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# Modeling the Evolution of Markets with Indirect Network Externalities: An Application to Digital Television

Sachin Gupta • Dipak C. Jain • Mohanbir S. Sawhney

Kellogg Graduate School of Management, Northwestern University, 2001 Sheridan Road, Evanston Illinois, 60208.  
s-gupta 7@nwu.edu • d-jain@nwu.edu • mohans@nwu.edu

## Abstract

The usefulness of a technology product for an end-user often depends on the availability of complementary software products and services. Computers require software, cameras require film, and DVD players require movie programming in order for customers to value the whole product. This phenomenon, where the demand for hardware products is mediated by the supply of complementary software products, is called an *indirect* network externality. Indirect network externalities create a two-way contingency between the demand for the hardware product and the supply of software products, and result in a strategic interdependence between the actions of hardware manufacturers and the actions of software providers. Indirect network externalities are gaining economic significance in technology markets, because hardware and software are typically provided by independent firms, and both sets of firms have an incentive to free-ride on each others' demand creation efforts. Despite the ubiquity of this phenomenon, it has largely been ignored in the marketing science literature.

We present a conceptual and operational model for the evolution of markets with indirect network externalities. The key feature of our framework is to model the *market-mediated dependence* between the actions of hardware manufacturers and software complementors, created by the *direct dependence* of consumer demand for the whole product on the actions of manufacturers as well as complementors. In addition, we incorporate marketing-mix effects on consumer response, as well as heterogeneity in consumer preferences for hardware and software attributes. We model consumer response using a latent-class choice model. To estimate the complementor response functions, we use a modified Delphi technique that allows us to convert qualitative response data into quantitative response functions. We integrate the consumer and complementor response models to create a simulation model that generates forecasts of market shares and sales volumes for competing technologies, as a function of marketing-mix effects and exogenously specified regulatory scenarios.

The modeling framework is of interest to new product modelers interested in creating empirical models and decision-support systems for forecasting demand in technology markets characterized by indirect network externalities. The decision-support aspects of the modeling framework should appeal to managers interested in understanding and quantifying the complex interplay between hardware manufacturers and software complementors in the evolution of markets with indirect network externalities.

We present an application of the modeling framework to the U.S. digital television industry, and use the framework to characterize the competition among analog and digital TV technologies. Our results suggest that complementor actions play an important role in the acceptance of digital TV technologies in general, and high definition television (HDTV) in particular. We find that forecasts that ignore the influence of indirect network externalities would be seriously biased in favor of HDTV. We illustrate how the modeling framework can be used to identify and profile customer segments in the digital TV market based on their utility for hardware-related features as well as programming-related features. We also illustrate the decision-support capabilities of the modeling framework by evaluating the sensitivity of the forecasts to varying marketing, regulatory, and complementor response scenarios. We derive implications for marketing and public affairs policies of the hardware manufacturers.

The developments in the digital TV industry generally support our finding that HDTV will be a niche product, and will diffuse slower than originally expected due in part to the lack of programming. The delays in the introduction of digital TV to the marketplace also suggest that most forecasts for infrastructure-intensive technologies like digital TV may be too optimistic simply because they underestimate the delays in agreeing upon technology standards and resolving regulatory debates.

(*Indirect Network Externalities; Demand Forecasting; New Products; Chicken-and-Egg; HDTV; Endogeneity; Heterogeneity; Conjoint Analysis; Technology*)