Network Effects -- Empirical Studies

Neil Gandal

Tel Aviv University

and

CEPR

July 2005

Email: gandal@post.tau.ac.il I am grateful to Pierre Regibeau and Paul Klemperer for helpful comments.

Introduction

A network effect exists if the consumption benefits of a good or service increase in the total number of consumers who purchase compatible products. The literature distinguishes between direct and indirect network effects.

In the case of a direct (or physical) network effect, an increase in the number of consumers on the same network raises the consumption benefits for everyone on the network. Communication networks such as telephone and email networks are examples of goods with direct network effects.

A network effect can also arise in a setting with a "hardware/software" system. Here, the benefits of the hardware good increase when the variety of compatible software increases. An indirect (or virtual) network effect arises endogenously in this case because an increase in the number of users of compatible hardware increases the demand for compatible software. Since software goods are typically characterized by economies of scale, the increase in demand leads to increases in the supply of software varieties. Examples of settings where virtual network effects arise include consumer electronics such as CD players and compact discs, computer operating systems and applications programs, and television sets and programming.

Given the dramatic growth of the Internet and information technology industries and the importance of interconnection in these networks, it is not surprising that there is a large theoretical literature on competition in industries with network goods. Important questions in this literature include

- The examination of the private and social incentives to attain compatibility
- The tradeoff between standardization and variety
- Modeling the dynamics of competition between competing networks
- How the private and social choice among competing incompatible networks differs when there are both early and late adopters

See Farrell and Klemperer (2005) and Klemperer's forthcoming article in this volume for further discussion.

Although relatively small, a growing empirical literature has developed to examine technological adoption of products with network effects. In this short article, I briefly discuss this literature. The empirical work can be organized by the issues addressed and the methodology employed. The primary issue addressed by the early literature is whether network effects are indeed significant; this work typically employed reduced form models. The essay first surveys early work in this genre. The essay then examines papers that employed structural methodology. The main advantage of this methodology is that it can address aspects of firm strategy, such as incentives to provide compatible products. The essay closes by examining key issues in empirical work on network industries.

Early Work: Indirect Evidence of Network Effects

Greenstein (1993), Gandal (1994, 1995), and Saloner and Shepard (1995) provide early evidence that the value of the "hardware" good depends on the variety of compatible complementary software. (Shy (2001) surveys many of the empirical papers discussed in this essay in greater detail than permits here.)

Software for the IBM 1400 mainframe could not run on succeeding generations of IBM mainframes while software for the IBM 360 could run on succeeding models. Greenstein (1993) finds that other things being equal, a firm with an IBM 1400 was no more likely than any other firm to purchase an IBM mainframe when making a future purchase. On the other hand, a firm with an IBM 360 was more likely to purchase an IBM mainframe than a firm that did not own an IBM 360. This result can be interpreted as a demand for compatible software.

Saloner and Shepard (1995) test for network effects in the ATM industry. In particular, they test whether banks with a larger expected number of ATM locations will adopt the ATM technology sooner. Since expected network size is not an observable variable, they use the number of branches as a proxy. The results suggest that banks with more branches will adopt earlier, which is consistent with virtual network effects.

Gandal (1994) estimates hedonic (quality-adjusted) price equations for spreadsheets to examine whether spreadsheet programs that were compatible with Lotus -- the de facto standard -- command a premium. The results, that consumers place a positive value on compatibility, suggest (I) direct network effects because people want to share files and (II) indirect network effects because compatible software enables the of transfer data among a variety of software programs. Gandal (1995) extends the analysis to Database Management Software (DMS) and multiple standards and finds that only the Lotus file compatibility standard is significant in explaining price variations, suggesting that indirect network effects are important in the DMS market.

Structural Models: Explicitly Modeling the Complementary Goods Market

Because hedonic price equations are a reduced form, rather than a structural model, parameter estimates associated with compatibility in Gandal (1994, 1995) may be capturing demand effects or supply effects or some combination of both. In other words, are consumers really willing to pay a premium for compatibility or is the marginal cost of compatibility relatively high? In the case of software, fixed costs of providing characteristics are quite significant, while marginal production costs associated with the characteristics are typically very small; they primarily include duplication of digital material. Hence in these papers, the estimated hedonic price coefficients on compatibility indeed measure consumer willingness to pay for compatibility.

Nevertheless, reduced form models are suitable for examining business strategies or conducting counterfactuals. Gandal, Kende, & Rob (GKR, 2000) develop a dynamic structural model of consumer adoption and software entry and use the model to estimate the feedback from hardware to software and vice versa in the CD industry. The

advantage of the structural methodology is that enables researchers to assess business strategies as well as examine conduct counterfactuals. In the case of business strategies, GKR (2000) show that a 5 percent reduction in price would have had the same effect as a 10% increase in CD variety in terms of increasing sales of CD players. They also show that if it had been possible to make CD players compatible with LPs, compatibility could have accelerated the adoption process by more than a year. This is just a "thought experiment" for CD players, but it has policy relevance for other systems like HDTV.

Rysman (2004) developed a structural model to examine the importance of network effects in the market for Yellow pages. The model includes a consumer adoption equation, advertiser demand for space, and a firm's profit maximizing behavior. He finds that consumers value advertising and advertiser's value consumer adoption, suggesting virtual network effects.

Advances in the estimation of discrete choice models of product differentiation – see Berry (1994) and Berry, Levinsohn and Pakes (1995) – have also been employed when testing for indirect network effects in differentiated product markets in several recent papers. Clements and Ohashi (2005), for example, use a logit model to test for indirect network effects in the U.S. video game market.

Key Issues in Empirical Work

As in most fields, empirical work is typically limited by the available data. A key problem exists when trying to estimate network effects in homogeneous product industries using time series data. For many network industries, technological progress drives down prices and costs. Hence an increase in the number of users on a network might be due to a network effect or to falling prices. See Gowrisankaran and Stavins for further discussion (2004). In order to estimate these effects, one must have additional data.

GKR (2000), for example, have data on the number of available compact disc titles at each point in time. Hence, in their model, the two main effects that lead to greater

adoption of CD players – lower prices of the hardware good and network effects due to increases in the number of titles – are measured separately. Nevertheless, that is only a start, since both of these variables are typically endogenous. Identification in GKR (2000) was possible only because there were data on the fixed costs of entering the compact disc production industry over time. These data were used an instrument for CD (title) availability. Additionally, case studies indicated that the CD player industry was quite competitive. Hence, the authors assumed that the price of CD players was exogenous due to the competitive industry. Without both of these assumptions, it would not have been possible to identify the model.

Additionally, there is the thorny issue of pricing in dynamic models of competition in network industries. Since hardware firms may want to subsidize early adopters in order to build up a network advantage and then (perhaps) charge a higher price when the installed base grows, pricing issues are dynamic; firms will take into account (current and expected future) network size when choosing their prices. Park (2004) develops a dynamic structural model of competition in an oligopolistic market with network effects that addresses the dynamic pricing issues; he then estimates the model for VCRs. To the best of my knowledge, this is the only empirical paper that deals explicitly with dynamic pricing issues.

A similar issue arises in dynamic models of competition in network industries when firms make investment in quality over time. Markovich (2001) examines the tradeoff between standardization and variety in a dynamic setting using numerical methods. With suitable data one might be able to use her framework to empirically examine dynamic investment incentives and pricing decisions in a dynamic setting with network effects.

Finally, there is a budding empirical literature on standardization via committees. Papers include Simcoe (2005), who examines the standardization process in various committees of the Internet Engineering Task Force and Gandal, Gantman, and Genesove (2005), who examine firms' incentives to participate in Telecommunication Industry Association standardization meetings.

References:

Berry, S, 1994. Estimating Discrete-Choice Models of Product Differentiation. RAND Journal of Economics 25, 334-347.

Berry, S., J. Levinsohn, and A. Pakes 1995. Automobile Prices in Market Equilibrium. Econometrica 63, 841-890.

Clements, M., and H. Ohashi 2005. Indirect Network Effects and the Product Cycle: Video Games in the U.S., 1994-2002. Forthcoming, Journal of Industrial Economics.

Farrell, J., and P. Klemperer 2005 (forthcoming). Coordination and Lock-In: Competition with Switching Costs and Network Effects. Handbook of Industrial Organization.

Gandal, N. 1994. Hedonic Price Indexes for Spreadsheets and an Empirical Test for Network Externalities. RAND Journal of Economics 25, 160-170.

Gandal, N. 1995. A Selective Survey of the Literature on Indirect Network Externalities. Research in Law and Economics, 17: 23-31.

Gandal, N., Gantman, N., and D. Genesove, forthcoming 2005. "Intellectual Property and Standardization Committee Participation in the U.S. Modem Industry." Standards and Public Policy, S. Greenstein and V. Stango editors, Cambridge University Press.

Gandal, N., M. Kende, and R. Rob 2000. The Dynamics of Technological Adoption in Hardware/Software Systems: The Case of Compact Disc Players. RAND Journal of Economics, 31: 43-61.

Gowrisankaran, G., and J. Stavins 2004. Network Externalities and Technology Adoption: Lessons from Electronic Payments. RAND Journal of Economics, 35, 260-276.

Klemperer, P. 2005. Network Effects. In Blume, L., and S. Durlauf eds., The New Palgrave Dictionary of Economics, 2nd edition, Palgrave Macmillan.

Markovich, S., 2001. Snowball: The Evolution of Dynamic Markets with Network Externalities. Mimeo.

Park, S. 2004. Quantitative Analysis of Network Externalities in Competing Technologies: the VCR Case. Review of Economics and Statistics 86, 937-945.

Rysman, M., 2004. Competition Between Networks: A Study of the Market for Yellow Pages. Review of Economic Studies 71, 483-512.

Saloner, G. and A. Shepard 1995. Adoption of Technologies with Network Externalities: An Empirical Examination of the Adoption of Automated Teller Machines. RAND Journal of Economics 26, 479-501.

Simcoe, T., forthcoming 2005. "Committees and the Creation of Technical Standards." Standards and Public Policy, S. Greenstein and V. Stango editors, Cambridge University Press.

Shy, O., 2001. The Economics of Network Industries. Cambridge University Press.

(1917 words – including references)